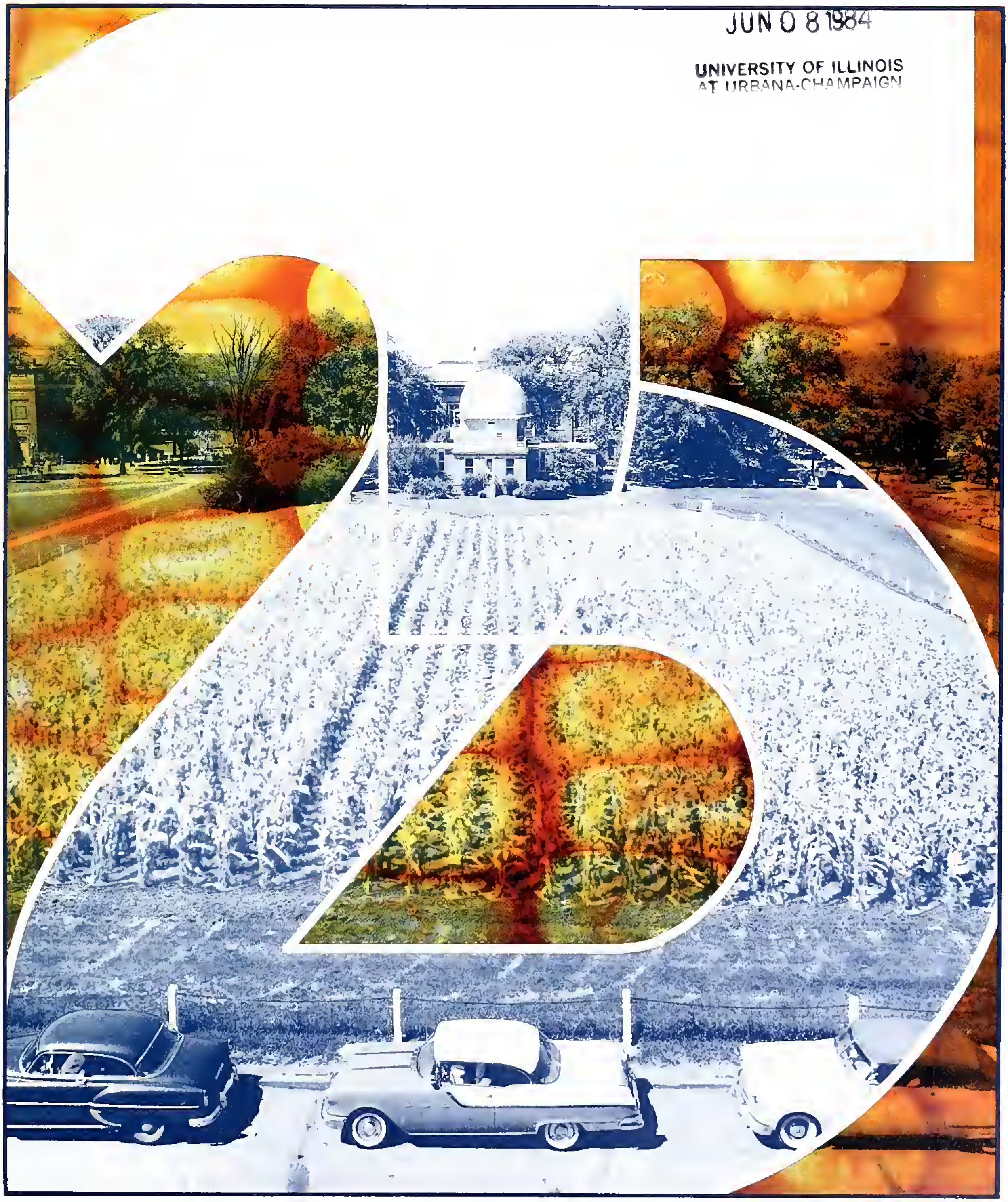
Illinois Research

Agricultural Experiment Station
Winter 1984



College of Agriculture, University of Illinois at Urbana-Champaign, Volume 26, Number 1

25th Anniversary Issue

On a winter day twenty-five years ago copies of the first issue of *Illinois Research* were mailed to readers who had expressed interest in other College of Agriculture publications. The purpose of *Illinois Research* today is much the same as it was then: "to report, in a non-technical manner, the research being done by the Illinois Agricultural Experiment Station." Our goal of responsible reporting to the citizens of Illinois remains unchanged.

The manner of reporting research *has* changed somewhat, however. As the pace of technological developments accelerates, we believe it imperative that we anticipate those advances and their possible consequences for society. *Illinois Research* now reflects the Station's awareness of its role in shaping the future of agriculture.

Another recent innovation in our manner of reporting — devoting each issue to a single theme such as nonmetropolitan Illinois or forestry — is intended to give our readers a fairly comprehensive view of the many scientific disciplines brought to bear in solving problems. Our subscribers now include scientists in Illinois and in many other parts of the world, people in agribusiness, state and national legislators, board members of Illinois farm organizations, educators, health care professionals, and Extension advisers, as well as homemakers and farmers.

In this 25th anniversary issue we pause to assess our present strengths and to recommend strategies for Illinois agriculture in the years ahead. We are entering a highly competitive era in the production, processing, and marketing of agricultural products. If Illinois is to maintain its advantage and continue to serve American consumers, the public must invest far more than it now does in agricultural research, development, and education. In the long run, consumers stand to gain if we make that investment.

Improvements in agriculture occur slowly from season to season. But a backward glance over the past quarter of a century reveals how far we have come in improving crop and livestock production. The socioeconomic aspects of Illinois agriculture are reviewed, and the remarkable advances in human health through improved nutrition are discussed in this issue of *Illinois Research*.

With bright, dedicated scientists and the modern equipment required for sophisticated research, the Illinois Agricultural Experiment Station will continue to serve the people of Illinois and the nation well into the 21st century.

Benjamin A. Jones, Jr., associate director of the Agricultural Experiment Station

The Cover

This issue of *Illinois Research* heralds the beginning of another twenty-five years of progress in Illinois agriculture. The famous Morrow Plots, pictured on the cover, serve as a reminder of the legacy entrusted to us in the rich soils of Illinois. Kernels of corn genetically engineered for maximum performance in this environment signify the wealth of our land.

"At a time unlike any in the past, we must envision the future."

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Illinois Research

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A Strategy for Strengthening Illinois Agriculture

Donald A. Holt

The history of American agriculture is a wonderful story of courage, sacrifice, hard work, and rugged individualism. Above all, it is an account of how a people developed and used technology to raise productivity to unprecedented heights. Transformation of the wilderness into an enormously productive agricultural industry paved the way for the industrial revolution in this hemisphere. Our cultural attitudes, living standard, free enterprise system, and international influence all have their roots in the unique development of American agriculture.

Land-grant institutions, created to educate the children of common people in the mechanical and agricultural arts, and the Hatch, McIntire-Stennis, and Smith-Lever Acts, which brought agricultural teaching, research, and extension together in the same institutional framework, were cultural and economic breakthroughs that transformed our nation. From these endeavors came the human capital and the technology required for dramatic increases in agricultural productivity.

It would be nice to end this story with "they lived happily ever after." But conditions change and American agriculture must adjust or lose its position of preeminence in the world. Loss of this position would have grave economic, social, and political consequences for the United States.

There was a time when the economic success of each farm family depended on the wits, muscle, faith, and determination of its members. While these qualities are still indispensable, the economic welfare of American farmers is now influenced by many outside forces, including domestic and foreign agricultural policy, the world economic situation, the weather in other countries, and political tensions among nations.

The University of Illinois College of Agriculture serves as the research and development arm of Illinois farming and also does much basic and developmental research for agriculture-related industries. The College provides the new technology that will keep Illinois farmers competitive. We also contribute to important policy decisions that influence agriculture in this state. A sound strategy for Illinois agriculture is urgently needed; it stands to reason that the College should play a lead role in developing it.

The state of American agriculture. To develop an effective strategy, we must first determine where we have been, where we are now, and where we want to go in the future. Each year vast amounts of data are collected on the status of agriculture. An examination of these data reveals several important facts.

Illinois agriculture is dependent on foreign markets. The United States exports roughly 30 percent of all its agricultural products. Illinois, more so than other states, relies on foreign markets, exporting more than 40 percent of its agricultural products and some 50 percent of its corn and soybeans.

The traditional American farm family is under great economic pressure. Relatively few in number, large farm operations having annual cash sales of $200,000 or more account for half the total agricultural production. These farms benefit from the economies of large-scale operations. Because they have strikingly lower per-unit costs, they can survive and continue to operate under price levels that work tremendous hardship on the medium-sized farms.

The number of small farms, those having annual cash sales of $20,000 or less, is actually increasing. Despite very high production costs and relatively low production levels, these farmers can survive by supplementing their income substantially from off-farm sources.

The medium-sized farms are generally under the greatest economic pressure. People who operate them are almost totally engaged in farming and have little off-farm income to cover any losses sustained in farming. Their cash costs of production are considerably higher than those for large farms, they cannot apply new technology as rapidly, and they are less diversified. Medium-sized farms are particularly vulnerable to the wide price fluctuations influenced by international markets. Family members are too busy to hold full-time jobs off the farm, yet their labor is not fully utilized on the farm.

Agricultural productivity is increasing at a slower rate than in the past. Research, development, and educational activities of land-grant institutions began to pay off in the 1920s and 1930s. From then until 1965 the productivity curve rose sharply. Between 1950 and 1965 alone, output per unit of input increased 230 percent. Crop production per acre soared 280 percent, and livestock production per breeding unit rose 190 percent. Between 1965 and 1980, however, productivity increases were only about half as great as those during the previous fifteen years.

Development of agricultural technology. *In modern, hi-tech ag-*

riculture, research and development require many highly trained specialists, sophisticated laboratories furnished with expensive equipment, and extensive field and feedlot research facilities. Early American farmers relied almost entirely on their own ingenuity to develop new and better ways of doing things. Our predecessors had a special knack for inventing labor-saving machines and other mechanical devices. American farmers are still very inventive and many are extremely skilled mechanics, welders, and builders.

Farming remains a unique industry made up of a large number of relatively small businesses. But times change. Even large farms don't have the resources to mount the research and development effort now needed for modern production. After about 1920, therefore, the major responsibility for agricultural research and development shifted from individual farmers to land-grant institutions and to large private firms whose customers are farmers.

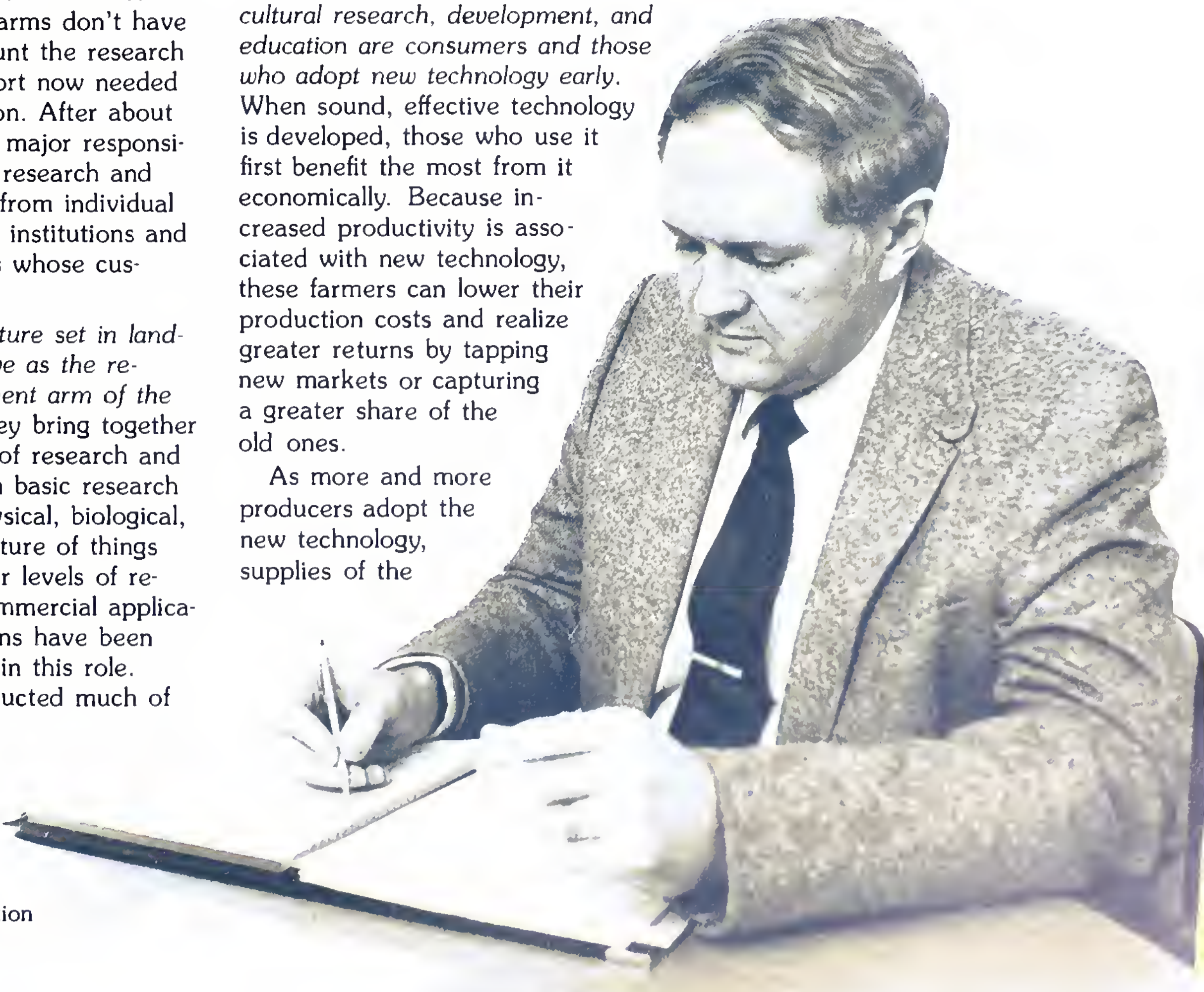
Colleges of agriculture set in land-grant institutions serve as the research and development arm of the farming industry. They bring together the whole spectrum of research and development — from basic research on the chemical, physical, biological, and mathematical nature of things through various other levels of research leading to commercial application. These institutions have been particularly effective in this role. They have also conducted much of the research for businesses related to agriculture.

Basic and applied agricultural research, agricultural teaching at the college level, and extension are parts of the same enterprise. Many people who conduct research in land-grant institutions also teach agricultural students and participate in the statewide extension networks. These efforts cannot be ranked in order of importance because if any one of them were missing, the entire system would not work. In fact, a big problem in countries with weak agriculture is the lack of closely linked research and educational efforts.

The primary beneficiaries of agricultural research, development, and education are consumers and those who adopt new technology early. When sound, effective technology is developed, those who use it first benefit the most from it economically. Because increased productivity is associated with new technology, these farmers can lower their production costs and realize greater returns by tapping new markets or capturing a greater share of the old ones.

As more and more producers adopt the new technology, supplies of the product increase, prices become more competitive, and consumers reap the benefits of lower prices and better quality. To keep ahead of the competition, farmers in the vanguard of hi-tech agriculture must have a constant flow of new technology.

Large nonagricultural corporations routinely use research and development activities to improve their own competitive position, often relying on secrecy or proprietary protection to do so. At land-grant institutions, however, the results of research and development are usually shared



Donald Holt, director of the Experiment Station

freely, not just with a select few, but with all farmers, students, scientists, and agribusiness people, even those in other countries. We do so for several reasons.

Simply from a practical standpoint, two million farmers would find it hard to keep a secret, even if they wanted to. Also, land-grant institutions have a tradition of free exchange because it would be impossible to teach agricultural students if much of the timely information were kept secret. Our scientists rely heavily on the exchange of information among universities and nations. If any university were to withhold its research results, it would soon find that other institutions and groups would do likewise. The net result of sharing is that new agricultural technologies tend to spread rapidly, thus increasing productivity and lowering the prices of agricultural products.

Investment in agricultural research. Most consumers are serenely confident that the shelves of their grocery store will always be full and that American agriculture will continue to provide an abundant supply of relatively inexpensive, high quality products. Unfortunately, many people don't connect agricultural research, development, and education with this abundance.

Investment in agricultural research, development, and education yields a very high return. The annual return on investment in these activities ranges from 10 percent to more than 200 percent and averages between 30 and 60 percent. Returns differ by commodity but are especially high in the North Central Region for research on corn, soybean, and livestock production.

Economists talk about the "marginal product" of investment. This concept is best explained by an example. An industry can invest money in many alternative activities such as research and development, advertising, capital equipment, and labor. Maximum total return to investment is attained when the last dollar invested in each alternative activity raises income one dollar. In other words, the industry continues to increase the investment in each activity as long as it brings additional net returns.

In agriculture, however, the marginal product is estimated at well over $10 for the last dollar invested in research on such major commodities as corn, wheat, and soybeans. This high rate of return indicates that increasing the investment in agricultural research, development, and education would pay off handsomely for both producers and consumers.

Agricultural research in the Midwest has a great spillover effect. The benefits of production-oriented research conducted in the Corn Belt are seven times greater for people living outside the region than for those living within it. The reason is simple enough: consumers are the ultimate beneficiaries of agricultural research, and most consumers of products grown in the Corn Belt live elsewhere.

It is therefore appropriate that agricultural research in Illinois should be federally funded. (At present about 20 percent of our Experiment Station research is supported by federal formula funds.) Ironically, people in certain other regions of the United States and in other countries have a greater return from the investment in Illinois agricultural research than from research in their own regions.

The low-income people of our nation gain the most from agricultural research, development, and education. Because their taxes are relatively low, they invest little in these activities. By increasing productivity and competition, research and development keep food expenditures down in relation to other family expenditures. People with low incomes get $25 to $30 back for each tax dollar invested in research on all agricultural products, whereas people with high incomes get $5 back for each dollar invested.

American agricultural research is extremely underfunded. Major industrial firms invest from 3 to 6 percent of their annual cash receipts in research and development. In Illinois, however, the public invests a total of less than 0.2 percent of the annual cash sales of crops and livestock for research on production agriculture. The total public and private investment in the College of Agriculture, including its research, teaching, and statewide extension programs, is less than 0.6 percent of the annual cash value of crops and livestock.

At land-grant institutions all over the nation, the equivalent of only about 0.5 percent of the cash sales of farm products is invested in research and development. Many states invest more than Illinois does, but none invests nearly as much as nonagricultural industries do for their own research.

Underfunding of agricultural research stems from at least four major causes:

- Those who allocate resources to agricultural research and development have opted for equity rather

than efficiency. They tend to spread the resources evenly by geography or population instead of investing where the returns are likely to be highest.

- Farming is not a unified industry. It is hard for farmers to make a collective decision to mount a large agricultural research, development, and educational effort. Yet they are aware of the need and allocate some checkoff money for this purpose.
- The general public believes that investment in agricultural research and development serves only farmers. Consumers of this nation do not see themselves as the primary beneficiaries of this investment and therefore fail to understand why they should bear a significant portion of the cost.
- Neither the farm population nor the general public is really aware of the high returns to investment in agricultural research and development.

Because food is abundant in this nation, people take the whole food production system for granted and see no great need to improve it. In that respect, agriculture is in much the same position now that the American steel and automobile industries were fifteen or twenty years ago. Since the United States dominates the markets, we complacently accept the status quo. As a consequence, our physical facilities are deteriorating and becoming antiquated, and production practices and product diversity are not being improved. Meanwhile, our foreign competitors are preparing for a major push into the world markets and into our own domestic markets.

Strategy. The preceding analysis of Illinois agriculture forms a basis on which to develop strategies. Of course, these strategies can be employed only if they are supported by a majority of farmers, agribusiness people, and the general public. Support is essential because collective political action is required, and large amounts of public and private resources must be allocated to specific projects related to agriculture.

Illinois agriculture needs to compete in world markets. Therefore, we should not adopt any national or state policies that would tend to bar our products from foreign markets or to price our products out of those markets. We must resist any drift towards protectionism in other parts of the economy. To remain competitive, the prices of agricultural products must not be supported or controlled artificially, but should be allowed to reach levels dictated by world supply and demand.

Prices will be especially low at times, and farmers who are highly capitalized, heavily indebted, or less efficient will be under great economic stress. Some of them will have to quit farming. Under those conditions, the tendency for small and medium-sized farms to get larger will probably continue. Harsh as the strategy may seem, it forces the industry to make necessary adjustments and to move towards greater efficiency.

History clearly reveals that when a nation tries to control production and the price of agricultural commodities, those commodities lose ground in world markets. Furthermore, great public costs are incurred and the agony of inefficient farmers, who lose out anyway, is prolonged. This has been the case when the United States has attempted to control production and the price of cotton, peanuts, sugar crops, and tobacco.

Investment in public agricultural research, development, and education must be increased substantially. The level should go up to at least 3 percent of annual cash sales of crops and livestock. Other industries consider this level the minimum investment needed to stay competitive. At least 50 percent of the support should come from the public through state and federal expenditures.

With the additional funds, major efforts should be mounted in biotechnology, computerization, postharvest technology, soil conservation, agricultural policy, agricultural finance, and consumer concerns related to agricultural products. It goes without saying that we must also sustain traditional agricultural research. The systems approach, which is not only a way of doing research but also a way of managing it, should be used as we expand our research and development effort.

Our system of applied research and our field and feedlot research facilities need to be greatly strengthened. The results of basic research will not be commercially useful until they are processed through the applied research system and adapted to conditions on the nation's farms. Strengthening applied research programs in Illinois will enable us to adapt new agricultural developments rapidly to specific conditions in this state. Illinois farmers will thus gain an economic edge from the new technologies before they become widely used.

The faster that new ideas are adopted to commercial application, the more attractive will investment in agricultural research be to public and private institutions. Federal research

agencies, including the U.S. Department of Agriculture, are moving away from applied research because they feel it is the responsibility of state and local governments and of private industry. Although the move is a major strategic error for the nation, it gives Illinois a chance to capture even more of the benefits of new technology than we could have done otherwise.

Our programs in international agricultural research and development also need to become much stronger than they are now. Surprisingly, as the agriculture of a country improves, it imports more, not fewer, agricultural products. To illustrate, the United States with its outstanding agriculture is the largest importer of agricultural products in the world. In part because of these imports, we have a vast array of food products to choose from.

American farmers have a high stake in the industrial development of other nations. Since some form of agricultural development must precede industrial growth, and since industrial activity generates the money to pay for imports, we should help other nations with this essential first step.

Higher education in agriculture should be put on a much stronger footing. The relatively low test scores along with the low high school percentile rank of the average undergraduate agriculture student bode ill for the future development of American agriculture. A major effort is required to attract academically well qualified young people into agriculture-related professions.

Administrators must be tough-minded in managing Illinois agricultural research, development, and educational activities. Much criticism has been leveled against the traditional research structure. Some of the criticism is based on a fundamental lack of knowledge about the system, but some is valid and deserves the close attention of agricultural leaders.

We can do a better job than we currently do, but we need a clearer definition of excellence in research, development, and education to compare our effectiveness with other institutions. Everyone involved must be dedicated to the highest standards of productivity, quality, and efficiency.

Taking the initiative. The strategies described above represent a huge undertaking. It is the agricultural equivalent of putting a man on the moon but, compared with the space effort, it will have to be sustained over a longer period. Although very costly, it will be less so than research and development activities of some individual industrial firms like IBM or General Motors. Surely agriculture, the most economically, socially, and strategically important industry in our country, deserves that investment, especially when the returns would be so high.

To launch this initiative and see it through to success, all the people whose vital interests are served by Illinois agriculture — and that includes virtually everyone in the nation — will have to unite in an unprecedented way. But the greatest share of the burden will fall on Illinois agricultural leaders, who must convince the rest of the population that this undertaking is critical and holds enormous promise for the future of our nation.

Donald A. Holt, director of the Illinois Agricultural Experiment Station

An Ecological Approach to Crop Management

William H. Luckmann, Marcos Kogan, and Jack R. Harlan

Agriculture today is poised between two overlapping eras — the era of chemical use and, before us, the era of ecological awareness. The first led to unprecedented yield increases, and the second will ensure the stability of those gains. Although chemicals will continue to be used in the years ahead, sensitivity to the environment will temper their use.

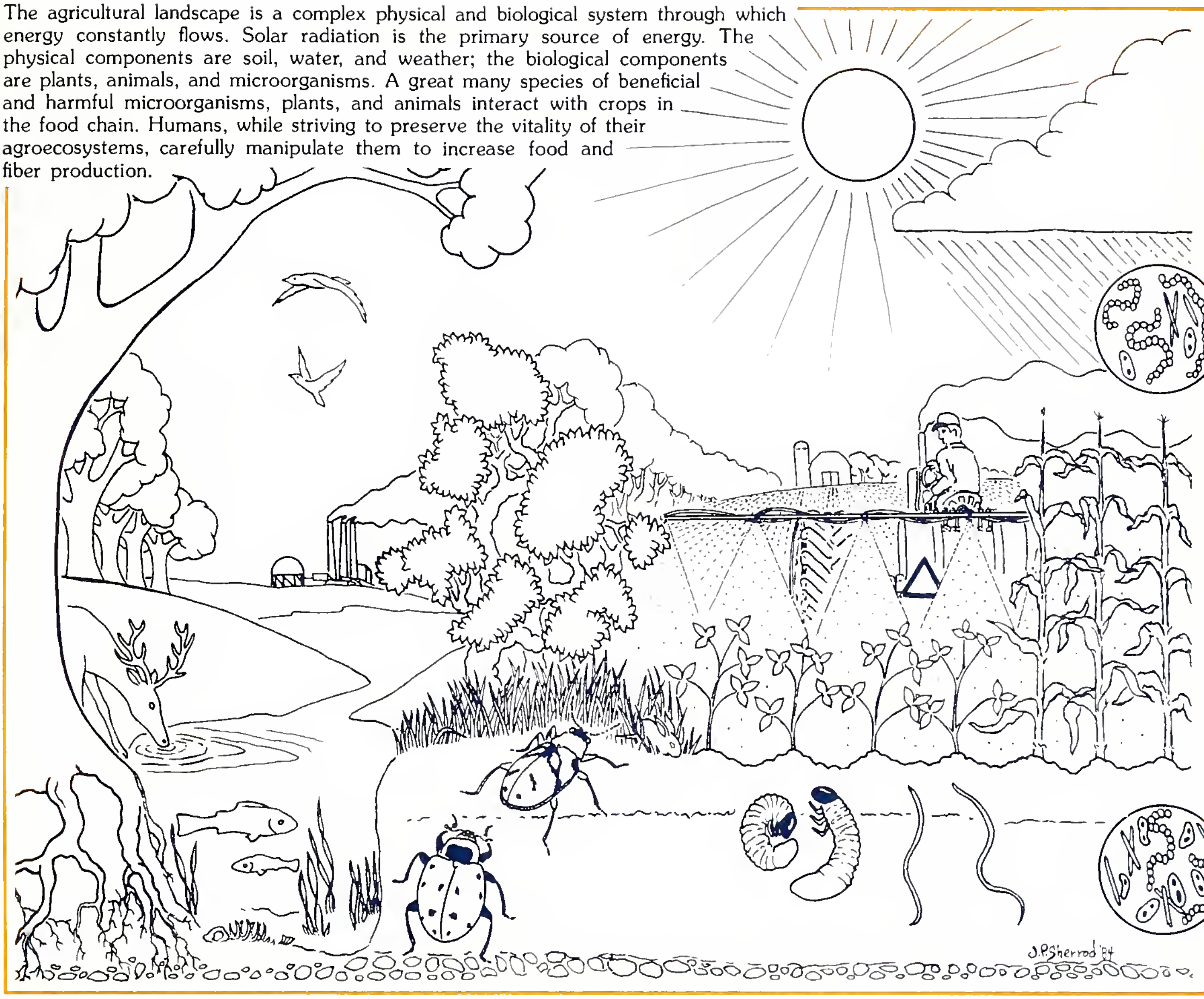
Looking Back: The Era of Agricultural Chemicals

What can truly be called the era of chemical use in agriculture began when synthetic pest control chemicals and fertilizers were introduced after World War II. Although they have posed some problems, on the whole agricultural chemicals have been a successful technology, reducing disease in humans and livestock and boosting food, feed, and fiber yields.

Several improvements introduced within a short period of time advanced the use of chemicals. The wartime munitions industry, which developed a tremendous capacity for fixing nitrogen, was converted to the peacetime production of synthetic nitrogen fertilizer. Farm machinery was engineered to improve soil preparation and application of chemicals, and crop varieties were adapted to take advantage of these resources. Advances in farm technology were the chief reason that labor and cropland became more productive.

Illinois agriculture has been based on vigorous research programs in the universities and in collaborating state and U.S. Department of Agriculture laboratories. For example, soil scientists provided better ap-

The agricultural landscape is a complex physical and biological system through which energy constantly flows. Solar radiation is the primary source of energy. The physical components are soil, water, and weather; the biological components are plants, animals, and microorganisms. A great many species of beneficial and harmful microorganisms, plants, and animals interact with crops in the food chain. Humans, while striving to preserve the vitality of their agroecosystems, carefully manipulate them to increase food and fiber production.



proaches to crop fertilization; as a result, use of liquid ammonia and urea is now widespread. Protection specialists improved controls for long-established crop pests and for the new invaders (e.g., giant foxtail, soybean cyst nematode, alfalfa weevil) that show up in Illinois every few years. Plant scientists did their part by improving varieties so that twice as many plants could be grown on the same unit of land. Since World War II, soybean yields per acre of land have doubled and corn yields tripled. In Illinois, harvested soybean acreage increased 127 percent and corn acreage 44 percent.

Pressures on the environment. While putting their energies into increasing yields, researchers and producers did not give enough thought to conservation or to the possible pollution of soil, air, and water. When a new technology was being developed or adopted, they seldom took into account the complexities of the environment. For example, the crop community contains not only weed, insect, and disease pests, but also harbors numerous minor herbivores, carnivores, parasites, decomposers, and other soil microorganisms that interact in the community.

Pressure was applied to this assembly of organisms by using crop plants with a narrow germplasm base, planting the same crop in the same field year after year, and repeatedly applying pesticides that often changed the pest complex or produced strains of pests resistant to previously effective controls. Inadvertently, we encouraged several crop pests, such as the western corn rootworm and the soybean cyst nematode, to become more widespread and destructive.

Techniques to reduce such problems have been investigated, however. Crop rotation, a good example of meshing technology into a production-protection system, is an important tactic in integrated pest management (IPM). Rotation controls northern and western corn rootworms, suppresses the numbers of corn nematodes and the soybean cyst nematode, and permits greater

flexibility in using herbicides to control weeds.

But not all crop acreage can be rotated, because soybean fields are erosion prone. Also, more acres are planted to corn than to soybeans in Illinois. Whenever possible, though, heavily infested fields should be scheduled for rotation with a nonhost crop. Enough acres can be rotated annually to greatly reduce some major pest problems and hence the cost of control. Decades of Illinois research show that growing corn continuously in the same field is the least efficient way to produce corn.

Pest control improvements. The past decade has seen important advances in the control of pests. We have broadened the germplasm base in crop plants. Many farmers have adopted crop rotation, and many use conservation tillage. The use of biodegradable toxic chemicals has greatly reduced pesticide persistence and biological magnification in the environment, a serious problem that appeared early with chemicals like DDT. Unfortunately, certain soil insecticides and herbicides are now so readily attacked by soil microorganisms that they are no longer very effective.

IPM has emerged as a better way to combat pests. Most importantly, researchers and producers have begun to understand the ecological complexities of chemical, mechanical, and biological practices in crop production systems. These systems place an increasing premium on management skills.

Looking Ahead: The Era of Ecological Awareness

Agricultural technology has taken some remarkable leaps during the past forty years. This trend will undoubtedly extend into the future, but with one noteworthy difference: more attention will be paid to keeping the agricultural environment healthy. As our understanding grows, we are coming to appreciate the delicate balance between pests and plants, soils and water. To maintain this balance, environmentally sound crop production and protection systems will have to be put together. These systems will call for new management strategies oriented towards conservation, efficiency, and profit.

Past performance is probably a good guide to the future. Even when technology and natural constraints come into balance, yields are not expected to level off. Despite four bad seasons in the last fifteen years, we have no evidence that a leveling trend has yet been reached. The slow, steady increase in soybean yields, largely because of plant breeding, will continue into the foreseeable future. The more spectacular increases in corn yields will also continue (Fig. 1). The key to current and future success is the integration of inputs already in place and plans to integrate new ones yet to be discovered.

Genetic engineering. One of the most important of these inputs is conventional plant breeding. Although genetic engineering will become significant in the breeding effort, it will not replace plant breeding as we know it. Genetic variation deployed in the field will be broadened still further, and use of exotic germplasm and wild relatives of crop plants will be expanded. Germplasm collections, to be enlarged considerably, will be more accessible to plant breeders. As a result, we should be able to manage diseases and pests more easily.

The development of more efficient crop varieties will be given high priority. Here is where genetic engineering and tissue culture techniques will come in. Although the new science is just now being introduced into crop improvement and protection, the University of Illinois and a number of private industries are already deeply involved in it.

So far we have succeeded in transferring useful genes, such as some for disease resistance, from one plant to another without hybridization. From a donor, we can transfer DNA fragments to a recipient by using plasmids or pollen as vectors or by injecting the DNA fragments directly into the recipient. Still in the early stages, these studies are very provisional but will undoubtedly develop significantly in the future.

Other areas of basic research promise to contribute to genetic improvement of plants and pest control. The aim of one of these areas is to identify the chemical clues that attract insects to crop plants. Another is trying to identify the chemical defense mechanisms that are mobilized by plants after they are attacked by insects or infected by diseases. These mechanisms seem to discourage further attacks.

Stress physiology. Crop plants have the ability to produce far higher yields than they do, but environmental stresses often block this ability. Adverse weather heads the stress list, with poor soils, weeds, nematodes, diseases, and insects close behind. Pests often multiply faster on stressed than on unstressed plants, thereby compounding the problem.

A two-pronged approach is usually used to improve plant productivity: first, the growth environment is upgraded, and then genotypes successful in that environment are selected. This approach will continue to be used. However, if we intensify research on stress physiology, we should be able to increase plant efficiency and productivity. The new knowledge will be applicable throughout the world.

IPM. Integrated pest management is defined as the use of pest control tactics that will ensure favorable economic, ecological, and sociological consequences. First proposed in the 1950s, IPM was not given much attention until the last decade. For the foreseeable future, most IPM programs will include pesticides as just one of several tactics to keep pest populations at noneconomic levels.

Society may impose constraints; however, the extent to which it does so will depend in large part on how carefully we use pesticides in the future. Until now, researchers, managers, and producers have been slow to integrate pest control tactics with production practices such as crop rotation. Many changes for the better are bound to occur once we perceive protection as an integral part of a cropping system.

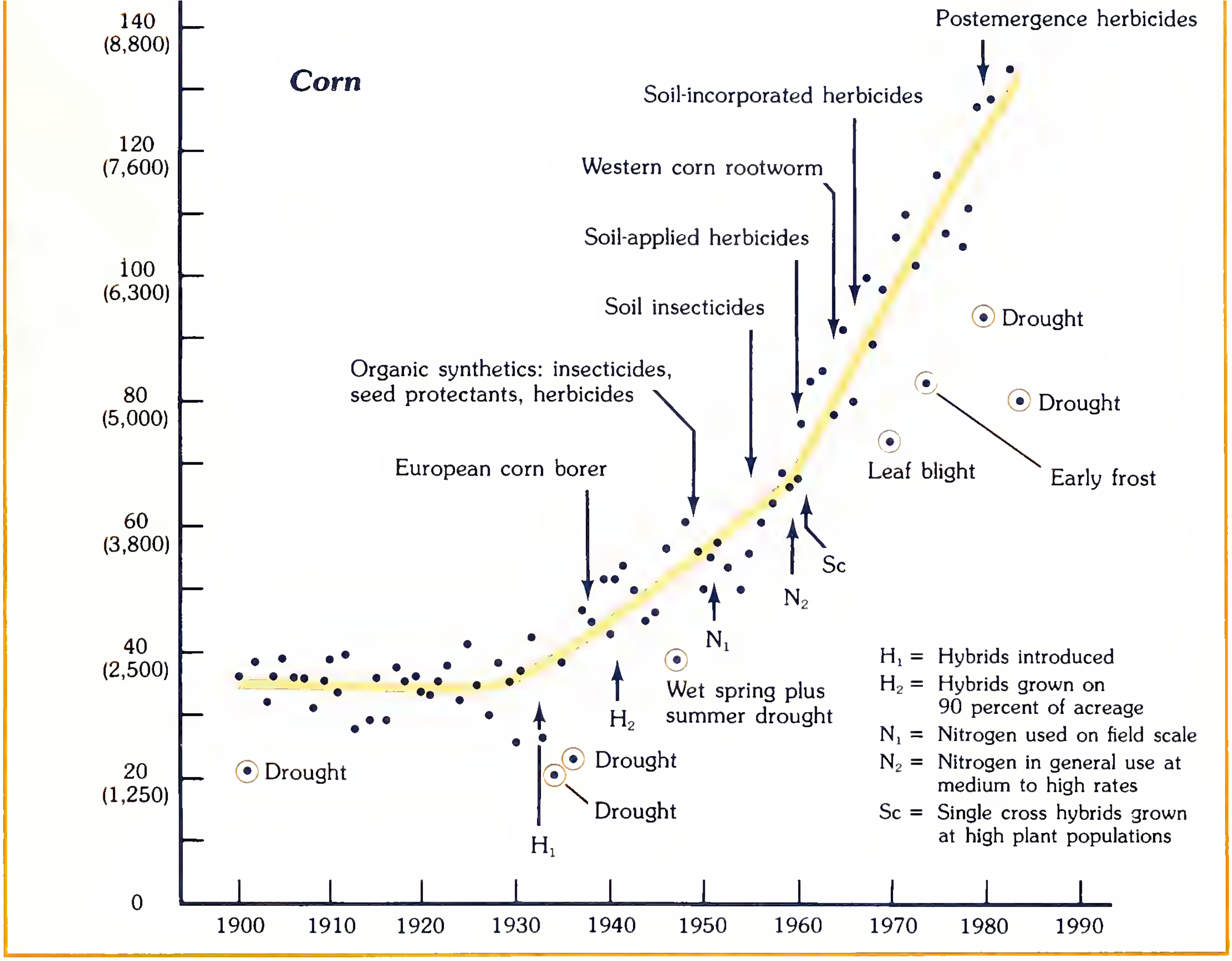
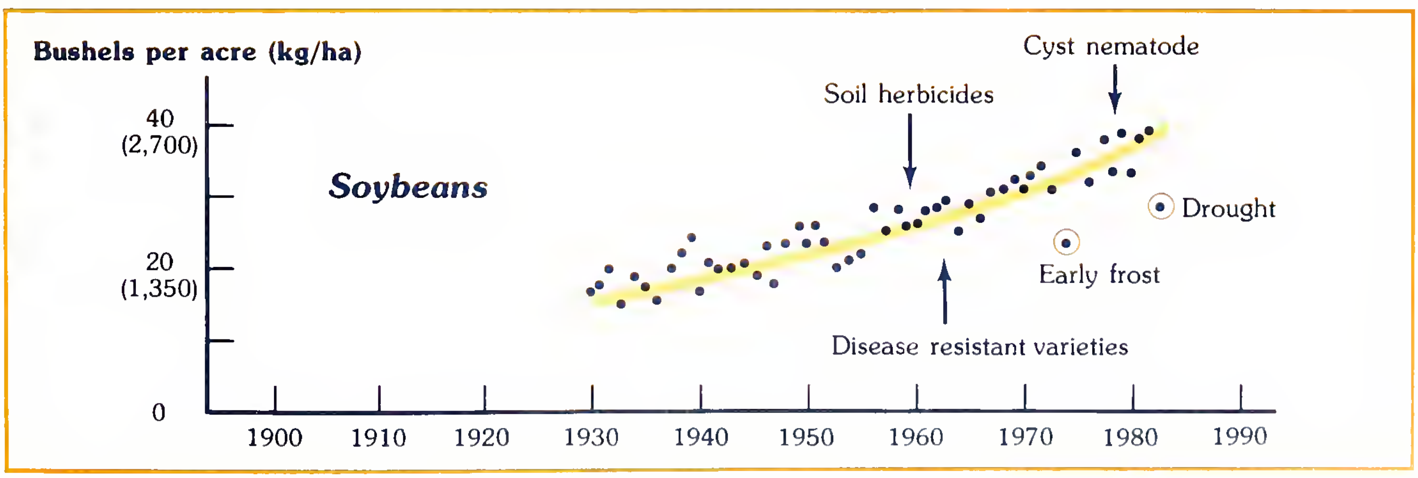


Fig. 1. Some major events in the production of corn and soybeans in Illinois are indicated below each curve; events related to protection are shown above. The two curves are radically different, largely because corn responds to nitrogen fertilizers and soybeans do not. Bean yields are much more stable and consistent than corn yields. In bad years, yields fall far outside the normal range; some of the causes for low yields are shown here. The steadily rising curves reflect the successful integration of research with practice. As new technology becomes available, Illinois farmers adopt it and are producing more than ever before. They are nevertheless still vulnerable in bad seasons. The corn curve clearly shows that some technological input is necessary to produce yields of more than 45 bushels per acre (2,800 kg/ha).

• Bushels per acre

• Below normal yield



Home computers. The evolution of crop management systems in Illinois is rapidly approaching a new stage that requires quick access to information sources. Solid biological information and reliable economic data are indispensable in planning rotation systems, allocating land to crops, selecting fertilizers, and making pest control decisions. Since some problems such as pest invasions leave little time for decision making, speedy transfer of information is essential. Now, with the help of microcomputers or personal computers, many producers can have useful information at their fingertips.

The type of information available on home computers will include

- identification or diagnosis of a pest problem
- up-to-date warnings based on field surveys
- alternative control decisions and control variables for pests and crops
- a whole array of crop management practices as well as marketing decisions

There are already simulation models that mimic crop growth and pest development under various field conditions. As more information is gathered, these models will be refined, making their usefulness in IPM programs immense.

Experience has taught us that there are no simple answers and that some production and protection practices have adverse repercussions on the environment. In a new approach that is emerging, the crop is perceived and managed as an agroecological system with many complex components. From all indications, the future will bring some very valuable advances in agriculture. As long as research programs continue to be vigorous and innovative, we can look to the years ahead with confidence.

William H. Luckmann, head, Section of Economic Entomology, Illinois Natural History Survey, and head, Office of Agricultural Entomology; Marcos Kogan, entomologist, Illinois Natural History Survey, and professor of agricultural entomology; Jack R. Harlan, professor of plant genetics

New Ways to Produce Superior Animals

W. R. Gomes

The American consumer enjoys the most bountiful table in the world, yet spends the lowest proportion of income for food, largely because of the efficient production of nutritious products from healthy animals. More than half of the nutrients, two-thirds of the protein, and four-fifths of the calcium in the American diet are derived from animal sources.

Direct sale of livestock and animal products contributes about 55 percent of cash farm income in the United States. Improvement in herds and flocks and their management has led to greater efficiency that has doubled the amount of milk obtained per cow, increased growth rates of meat-producing animals by 25 to 50 percent, cut in half the time necessary to produce chickens for market, and increased egg production by some forty eggs per year — all within little more than twenty-five years.

Since 1959, farm income from animal products has increased steadily, even though livestock production has decreased as a proportion of total farm income in Illinois (Fig. 1). Hogs and cattle in particular have played an increasing part in Illinois animal operations, but dairy cattle continue to contribute significantly to farm income (Fig. 2). Although the number of dairy cows declined 64 percent between 1959 and 1983, a concomitant 65 percent increase in milk production per cow has kept dairying an economically important industry.

The First Twenty-Five Years

The rich history of research efforts in animal science, dairy science, and veterinary medicine at the University of Illinois has been chronicled in twenty-five volumes of *Illinois Research*. The first hundred issues of the publication reveal not only the successes, and some failures, of research on campus, but also a picture of people and change, of ideas and programs, of continuing effort and progress. From theory to application, the important relationship between basic and applied research can be seen in reports on animal improvement.

People. Since its founding, the Illinois Agricultural Experiment Station has been populated with bright, dedicated scientists. These men and women combine a thorough understanding of industry problems with a knowledge of the biological principles underlying the animal functions that affect those problems.

In his prophetic book, *Future Shock*, Alvin Toffler suggests that problems will be solved in the future by ad hoc teams of experts from various fields working together on short-term projects. Although Toffler may be correct, he may also be behind the times, for early issues of *Illinois Research* are full of examples of research teams drawn from animal science, dairy science, veterinary medicine, agricultural engineering, agricultural economics, agronomy, and entomology to address questions of mutual interest. To sustain our rate of scientific progress, however, we must continue to attract outstanding staff and students and provide adequate facilities for them.

Biology and genetics of farm animals. Research in Illinois is rooted in the basic sciences. Working closely together, biochemists, geneticists, microbiologists, physiologists, and veterinary pathologists

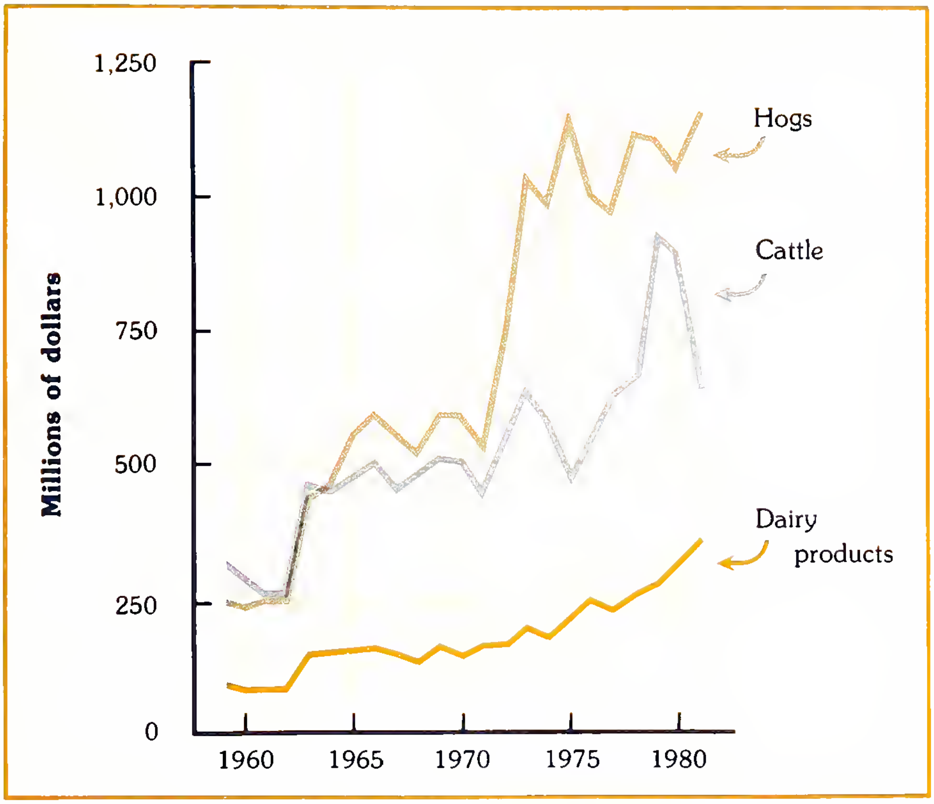


Fig. 1. Illinois farm income from hogs, cattle, and dairy products, 1959 through 1981. Sale of livestock products has contributed significantly to farm income during this period.

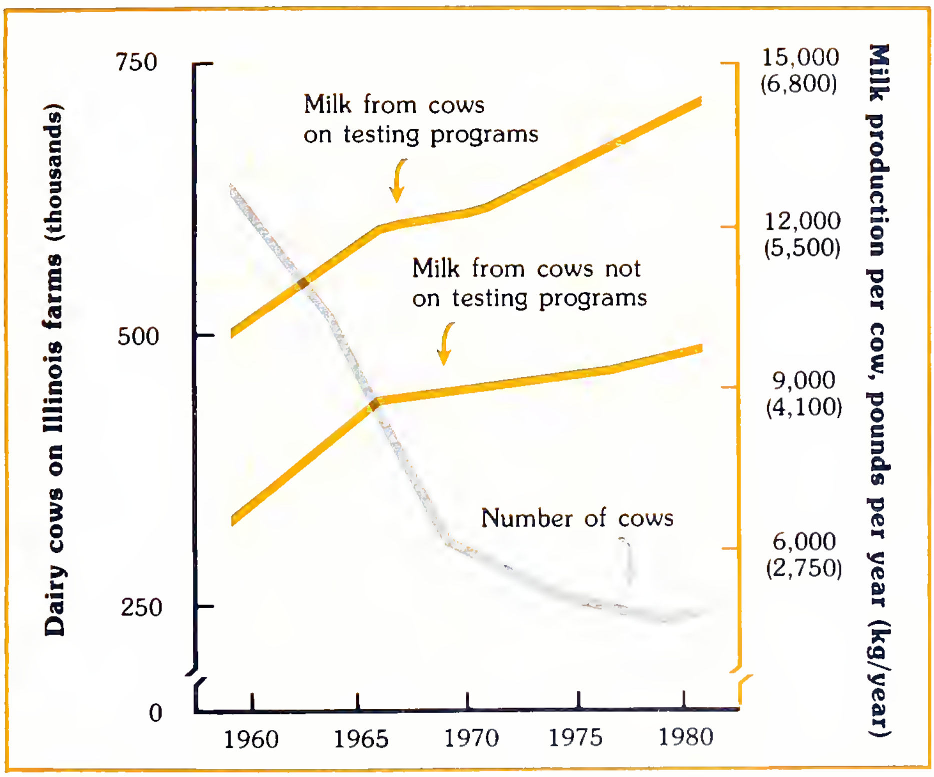


Fig. 2. Number of dairy cows on Illinois farms; annual milk production for cows tested through the Dairy Herd Improvement Association (DHIA) and for cows not on DHIA testing programs, 1959 through 1981. An increase in milk production per cow has offset a decline in the number of cows in Illinois.

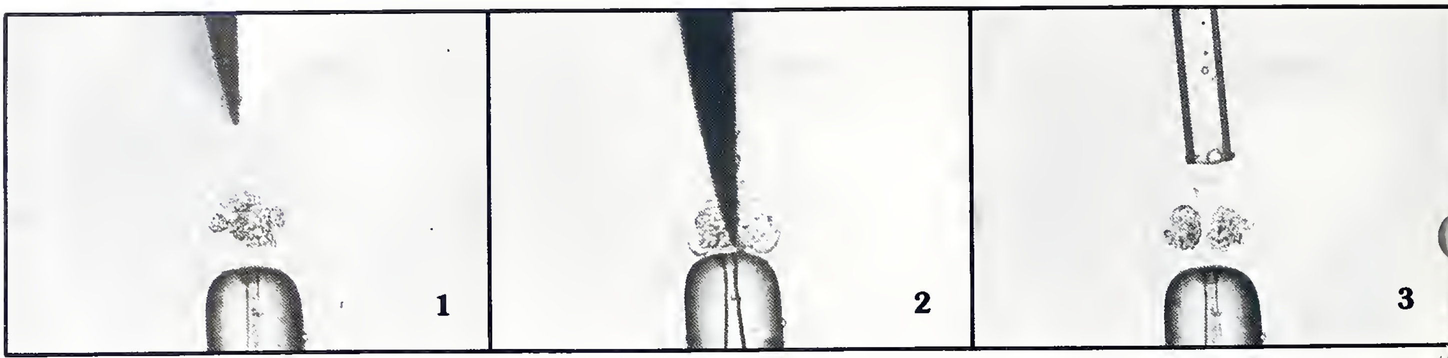
have gained a better understanding of vitamins, amino acids, and minerals in animal nutrition; the principles of animal reproduction; natural and induced immunity in animal health; microorganisms in the nutrition of ruminant animals; and the biology of milk, meat, and egg production.

The development for research use of computers, radioactive isotopes, and electronic devices for measuring physiological changes can also be added to this list of achievements. Although frequently overlooked, the importance of basic research to the eventual solution of problems on the farm cannot be overstated.

During the last twenty-five years, genetic improvement in farm animals can take much of the credit for increased production. To speed the progress of genetic change, scientists use computers extensively for maintaining animal records, calculating selection indexes, and devising mating plans. Physiological measurements such as blood types are being correlated with health problems or producing ability. The hybrid vigor generated by crossbreeding is being studied, and identical twins have been used to define more clearly the genetic basis of animal differences.

Nutrition. As a result of research, animal nutrition has improved on several counts. Once we realized that energy is the most limiting nutritional factor for genetically superior animals, we increased the use of high-energy feeds. In addition, diets to promote maximum performance have been designed to include research findings on protein and amino acid requirements, vitamin and mineral needs, and the appropriate balances for fiber and other constituents.

In response to the rising cost of feedstuffs, animal nutritionists are taking a close look at industrial byproducts that might be suitable for farm animals, particularly ruminants. Byproducts of the sugar, corn syrup, brewing, and distilling industries are now widely used in animal feeds, as are nonprotein nitrogen sources such as urea. Even animal wastes have been "recycled" to salvage nutrients that would otherwise be lost.



Animal reproduction and health. University of Illinois scientists have done key research on the physiology of mammalian sperm cells. Procedures for storing frozen semen have grown out of this work and, as a result, dairy cattle have improved dramatically through the use of artificial insemination. Bees, poultry, and other farm animals have also benefited from artificial insemination, along with pets, zoo animals, and humans.

Progress in female reproduction has not fared so well, but the way has been paved for improvements by studies of the basic mechanisms involved in estrous cycles, fertilization, and pregnancy in cattle, pigs, and sheep. In recent years, procedures for controlling reproductive cycles, superovulation, and embryo transfer have been developed from this information. The animal industry stands to benefit from studies of in vitro fertilization and embryo transfer conducted on our research farms.

Throughout the long years of research, veterinary and animal scientists have taken large strides in diagnosing, treating, and controlling dozens of animal diseases. Basic studies have enabled us to develop weapons for battling hog cholera, transmissible gastroenteritis, Johne's disease, nematodes, and other parasites, to name just a few of the many diseases.

To aid in their war against disease, Illinois veterinary scientists have developed germfree animals and established a Diagnostic Research Laboratory for livestock and pets. Traditionally, veterinarians concentrated on treating disorders in livestock. Today, the diagnosis, monitoring, and improvement of herd health are paramount in the cooperative research of Illinois veterinary, animal, and dairy scientists.

Management. All of these activities are pulled together by management specialists. For example, they work closely with environmental physiologists and agricultural engineers to determine optimal housing conditions, with nutritionists to select diets for maximal performance, with physiologists and geneticists to breed better animals, and with veterinary clinicians to improve herd health. Management specialists are also responsible for research on herd economics and for developing efficient procedures. Computers, as well as electronic and automated devices, are indispensable in this work.

The Next Twenty-Five Years

The wildest predictions made a quarter of a century ago have fallen far short of reality in 1984. But we can get at least a glimpse of the future by projecting from recent advances in biology and agriculture. One of the wonders to come will undoubtedly be custom-designed embryos for producing superior animals. I will describe here various techniques — some of them familiar and others yet to be devised — that may be used in micromanipulation.

Embryo manipulation. Superovulation, a technique that has been around for some time, causes mature females to release many times the usual number of ova. After fertilization, the ova are transferred to surrogate mothers. A few cells taken from an embryo before transfer can be examined to ascertain the sex. The procedure has limitations, however: the fresh embryo has to be transferred before sex test results are available, and cell removal significantly increases embryonic mortality. Scientists are now trying to perfect cell removal and storage so that transfer of undamaged embryos can be delayed until sex has been determined.

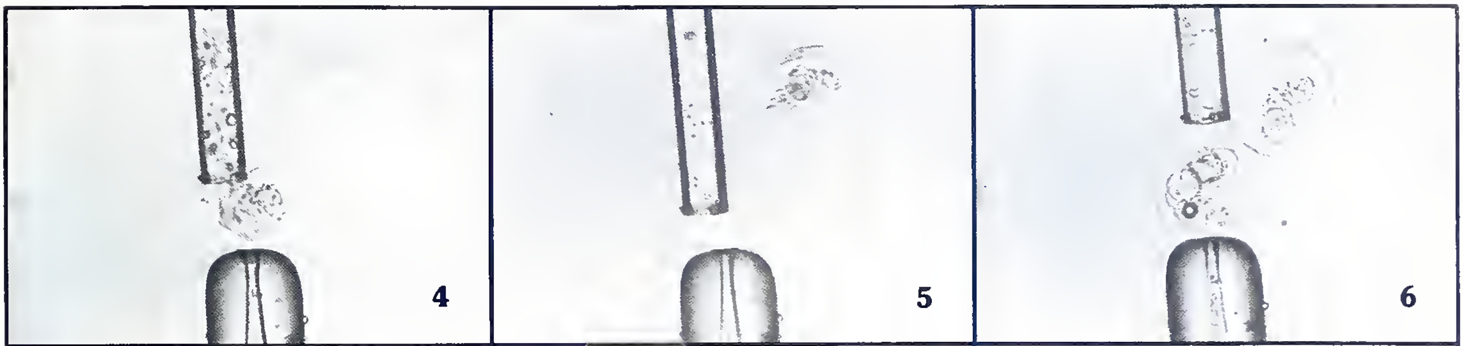
Another way to obtain embryos of the preferred sex may be through using immunological procedures adapted to prevent the growth of, say, male embryos; the ones recovered would then be females only. Applied at a different level, the same procedures might selectively destroy either the X-bearing or the Y-bearing sperm, again producing offspring of the desired sex.

Today, the birth of cold-stored embryos is no longer surprising, now that we know more about freezing and storing them in liquid nitrogen. Procedures for thawing and delivering embryos to host females are steadily improving. In fact, their routine, commercial use may be just around the corner.

In vitro fertilization, or mixing eggs and sperm in the laboratory, first gained worldwide attention with the birth of the so-called test-tube baby in England several years ago. Even before then, however, the technique was widely used in experiments with laboratory animals. Live births after in vitro fertilization are not uncommon in farm animals.

Taking this idea one step further, we may someday be able to collect eggs from a prepubertal animal, fertilize them in vitro, and transfer them to adult hosts. The procedure would allow us to shave two or three years from the bovine generation interval. With proper selection

Photos by Joel Lawitts



of donor calves, genetic progress could thus be speeded considerably. Another possibility may be to take an ovary or a small part of one from a newborn female and induce the production of mature oocytes in vitro. Once produced, these eggs could be fertilized in the test tube, thereby salvaging the millions of oocytes lost before and after puberty.

A multicelled embryo, whether recovered from a female or produced from in vitro fertilization, can now be physically or chemically split to form two embryos and split again to form four. In the latest experiments, scientists are taking nuclei from these embryos and transferring them to enucleated eggs. When successful, the technique will allow multiple clones of the original embryo to be split.

A similar scenario calls for the transfer of nuclei from body cells of a superior adult to enucleated zygotes, thereby cloning the individual for posterity. Fiction has already popularized this idea, for example, in *Jonathan, Son of None* with the cloning of John F. Kennedy and in *The Boys from Brazil* with the genetic reproduction of Adolf Hitler. The author of *In His Image* claims the cloning of a man, and one report in the scientific literature describes the transfer of a nucleus from an adult human cell into an enucleated egg with subsequent cleavage. To date, however, only experiments with amphibians have produced adult animals.

Some years ago, scientists in at least two laboratories described the production of chimeric mice, that is, mice with two cell lines derived from two early embryos that had joined. The success of this procedure may be a very important link in introducing genetically engineered material into the genome of livestock.

Carrying micromanipulation further, scientists have removed one pronucleus from a fertilized mouse egg and chemically induced the remaining pronucleus to duplicate. The resulting embryo is homozygous for every gene. Hundreds of mouse embryos have been produced in this fashion in at least three laboratories. If adaptable to livestock species, this procedure could be used to provide "seed stock" for producing offspring with maximal hybrid vigor.

Genetic manipulations. Biotechnology, recombinant DNA, genetic engineering — all of these words generate considerable excitement. To the biological scientist, they conjur up visions of new ways to study living organisms. To the medical practitioner or veterinarian, they mean the potential for producing old drugs in large quantities and new, inexpensive wonder drugs. To the livestock producer, they hold forth the promise of healthier animals that grow faster and more efficiently than those now in their herds and flocks. A few of the many intriguing possibilities are discussed below.

Monoclonal antibodies, which have already revolutionized the biological industry, are used for diagnostic tests and assays of many naturally occurring compounds. Eventually such antibodies will probably be widely used to passively immunize animals against acute or chronic diseases. Although in the realm of cure rather than prevention, this application may, in some cases, save individuals or entire herds and flocks.

The monoclonal antibody may also help us pinpoint sites of disorders associated with specific diseases and

A micromanipulator, operated by Charles Graves (below), is used for splitting a single embryo to form identical offspring. During manipulation, the embryo is held in place by a bore that provides suction (1). An incision (2) is made in the zona pellucida (shell), which is the noncellular glycoprotein layer surrounding the embryo. The embryo is then cut into two equal parts. One half is removed by a pipette (3, 4) and placed into an empty shell (5), while the other half is left in its original shell. The two identical embryos (6) are then transferred into foster mothers for development. At the stage of development pictured here, a bovine embryo measures 140 microns in diameter.

thus enhance our understanding of prevention. Moreover, were we able to repopulate the body with cells that produce monoclonal antibodies in vivo, they could ward off many contagious diseases.

Recombinant DNA molecules have already been introduced into bacteria for the production of growth hormone, insulin, interferons, and many other compounds. The next step is of course the genetic engineering of farm animals. In several experiments, a mammalian gene added to mouse embryos in culture has been incorporated, replicated, and expressed in the live mouse growing from the embryo. The most striking example is the rat gene for growth hormone, which produced transgenic mice twice the size of their littermates.

By adapting such techniques to farm animals, we might be able to turn on or off existing genes in the animal. For example, the rat has a gene for a protein that is synthesized in the milk. Although other species have the same gene, the protein of interest is not secreted. If we could turn this gene on in cows, considerably more milk protein might be produced without altering other normal functions.

In spite of rapid advances in biotechnology, many obstacles will delay application to the animal sciences. Until we understand the basic phenomena of action and controls, our efforts will be fraught with error and loss of time and money. However, with well trained scientists supported by the necessary resources, the biotechnical future of animal agriculture looks bright.

W. R. Gomes, professor and head, Department of Dairy Science

Socioeconomic Research in Agriculture

Chester B. Baker

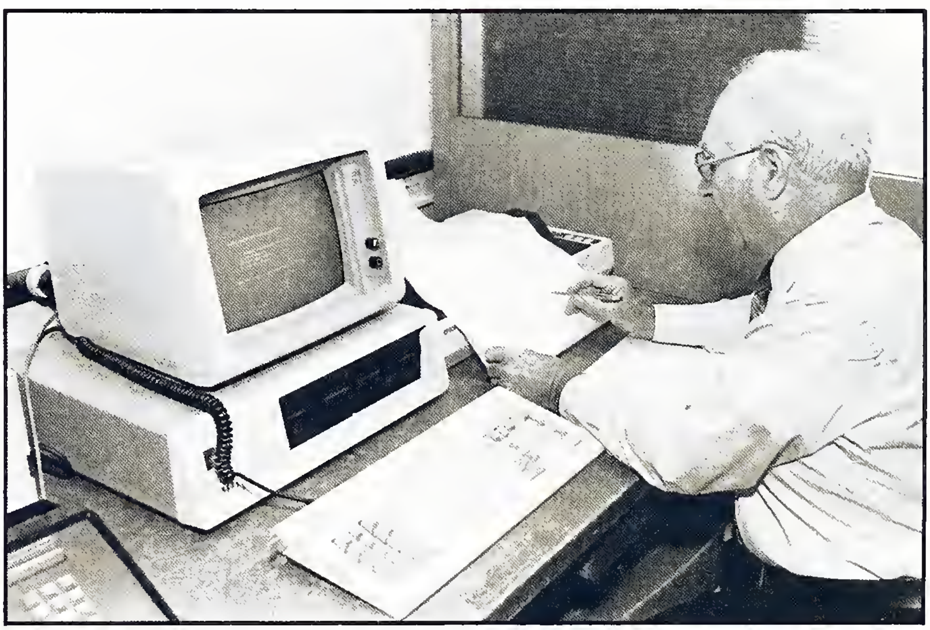
U.S. agriculture has grown large and sophisticated. Socioeconomic problems related to this enterprise have grown accordingly. This article highlights major areas in which social scientists have responded during the past twenty-five years and directions that socioeconomic research is likely to take in the future.

Commercial Agriculture

Farm management and production economics. By 1960, researchers were studying farm management principally from the standpoint of production economics. In Illinois as elsewhere, the research agenda featured statistical studies of production variables, as well as costs and returns of farm enterprises and production practices. Meanwhile, expanding computer capacity was providing researchers access to programming models for use in joint studies of marketing, finance, household, and production strategies and constraints.

The agenda then shifted toward studies of farm growth and capital accumulation. Risk specifications became feasible, improving the capacity of the models to reflect uncertainty in decision making. Simulators were developed to account for dynamic relationships.

In the next twenty-five years farm management research will probably become more interdisciplinary. Biophysical sciences, for example, will



Chester Baker explains the merits of computer-based models; the printout of a summary for land purchase options appears on the opposite page. Personal computers are a convenient tool for helping researchers construct socioeconomic models for agriculture.

be integrated with production, marketing, and financial management. Models will become increasingly precise, as rapid developments in computer hardware and software lower the cost of acquiring and managing information. Such changes will create demands for innovations in recordkeeping services, an area in which Illinois is widely recognized as a pioneer.

Marketing and prices. Farmers' problems in marketing their output have been a major focus of marketing and price research. Extension outlook programs are backed by studies to improve forecasts and the associated educational efforts. Research has generated useful information on locational economies for agribusiness firms and on the effects of changes in technology and public policy on spatial distributions and economic efficiency. In addition, research has supplied estimates of national and international trade flows for Illinois farm commodities and has examined the structural aspects of commodity markets.

During the past quarter century, the Department of Agricultural Economics has also contributed to the design of grades and standards that improve marketing efficiency and quality management of farm commodities after harvest. A continuing program is focused on price discovery and on the management of costs and capital in agribusiness firms.

Future research will expand the production and consumption components of trade and market models and will refine the international aspects of commodity and capital markets. Specifications will improve for risk, expectational behavior, and state, quasi-state, and cartel-like organizations in international trade. With prospective increases in the costs of capital and transportation, time and space management may well grow in importance.

Agricultural finance. Problems of financial management and financial markets are the focal point of research in this area. Studies of investment and capital accumulation and credit in the 1950s and 1960s reflected unprecedented economic growth rates for farm firms in those decades. In the 1970s and early 1980s, the emphasis shifted to the cash, credit, and debt aspects of risk management, reflecting increases in economic risks. Financial management has been integrated with production, marketing, and household management. Research monitoring the financial markets revealed substantial responses to changes in the farm sector and in the national and international economies. Interest rates became more variable and credit supplies less so.

In the next twenty-five years our research agenda will continue this shift toward problems in financial markets, with issues of regulation and public credit growing in importance. Repayment plans will be designed that are more appropriate for farmers' repayment uncertainties. Institutions and policy alternatives will become more responsive to the risks encountered in the farm sector. International capital markets will become increasingly important for agriculture, as will financial aspects of management and commodity markets.

Rural Community Organization and Development

Following World War II, employment in agriculture lessened, many people moved to the city, and the population base for providing local services declined in rural Illinois.

FINAL SUMMARY OF LAND PURCHASE OPTIONS

	OPTION 1	OPTION 2
Length of loan	25 years	30 years
Purchase price	1000.00/acre	1000.00/acre
Downpayment	100.00/acre	100.00/acre
Principal(total)	900.00/acre	900.00/acre
Interest(total)	1437.20/acre	1964.14/acre
Principal and interest(total)	2337.20/acre	2864.14/acre
Total payments	2437.20/acre	2964.14/acre
Interest rate	9.25 percent	10.00 percent
Tax rate	30.00 percent	30.00 percent
Tax savings	399.32/acre	478.82/acre
Discount rate	8.00 percent	8.00 percent
Net present value	880.48/acre	912.60/acre

Press "HOME" for menu

Early in this period, researchers concentrated on ways to help people, especially from farms, prepare for urban living and industrial employment. Communities in turn needed to adjust to out-migration and erosion of the economic support base. Ironically, better schools were needed to prepare rural students for entering the mainstream of society at the very time when support for local schools was dwindling.

In the 1960s, research shifted to methods of strengthening the rural economic base and maintaining a suitable living environment. Industry's invasion of rural areas, as illustrated by the large steel mill built in Hennepin, Illinois, was analyzed. In the 1970s, migration patterns in Illinois reversed, producing population growth in many rural counties. Added emphasis was given to research on local employment, the provision of services, and the tax structure.

Information processing and other technological developments will allow employment to become increasingly decentralized. Future research will take a hard look at the capacity of rural areas to compete for new jobs. Implications for part-time farming, the service structure of communities, and the distribution of opportunities among rural residents will almost certainly be highlighted on the research agenda.

Natural Resources Economics

Studies of our valuable land base have long dominated natural resource economics; land tenure, land markets, and land taxation have been stressed. Policies related to the control of soil erosion are being analyzed and pest management options emphasized as a result of mounting environmental concerns. Studies of agriculture as both source and consumer of energy have also come to the fore. New capabilities for modifying weather have stimulated research on the possible agroeconomic effects.

In the next twenty-five years, researchers will be concerned with the tightening of agriculture's energy and capital constraints, a trend that reverses a long period of relaxation. Environmental issues will take on added significance with the transfer of new genetic technologies from lab to field, the introduction of new pest control measures, and the escalation of soil and water management issues.

Along with other sectors, agriculture will have problems of hazardous waste management, as well as those related to tenure, exchange, and taxation of land. Resource and environmental issues frequently attract public attention; therefore, research on the processes involved in public decision making will be very important.

International Agricultural Developments

In recent decades, our social scientists have linked research in international agricultural development closely with institutional development, the International Soybean Program (INTSOY), and the research topics of graduate students from the United States and developing countries. They made major contributions as agricultural universities were established in South and Southeast Asia and Sub-Saharan Africa. Rural sociologists and agricultural economists studied new technologies in developing countries and provided technical assistance in studies of production systems and of commodity and financial markets. Theses of graduate students ranged over the full spectrum of topics found in domestic research.

Activities in future decades will emphasize establishing graduate programs and strengthening universities in regions previously bypassed. The International Program for Agricultural Knowledge Systems (INTERPAKS) should improve the link between research and extension. The financing of economic development will continue to increase in importance. Skills for developing models of farmer decision making, multiple cropping, and similar activities will be increasingly useful in domestic research. The demand for international expertise will accelerate as international components are needed in models to study U.S. problems.

Agricultural and Food Policy

In contrast to the "elder statesman" approach, public policy research in recent years has come to rely more on models for predicting the effects of policy alternatives on the farm sector. In Illinois as elsewhere, estimates of coefficients of farm commodity demand and supply relationships were sought for such models and applied to help us understand the economics of evolving public policies, the factors that determine them, and policy alternatives. Values, goals, and politics became parts of the analysis. Rural poverty, the distribution of wealth and income, and the effects of food policy on urban and foreign poverty were researched, as were the economic aspects of food safety.

In future years, the models used for policy research will be expanded to better accommodate international developments and trade. The more comprehensive models will also improve analyses involving interrelationships among social sciences and the production and food sciences. Analyses of domestic and foreign food distribution will be included, along with the more traditional problems of prices, incomes, and risks. The economics of soil conservation is becoming linked with production control and natural resource management and with pest and weed management.

Increasing attention will be paid to the economics of food safety. The agricultural and food sectors are becoming more integrated, international, urban, and commercial. More effort will therefore be put into creating institutions that can adjust to these changes.

Agricultural Law

In 1939, H. W. Hannah started the agricultural law program at the University of Illinois, the first program of its kind in a U.S. university. Initially, the program focused on courses and public service. By the 1970s, however, it had become apparent that research would be a significant part of the program. Extensive work in water and drainage law

led to major revisions of the Illinois Drainage Code. Animal and veterinary law have also been researched, as well as the legal bases for rural universities in developing countries. In recent years, land use, environmental issues, protection of farmland, and taxation were studied in greater depth and a program was begun in tax-related issues.

Future research will include legal aspects of the use and protection of natural resources, agricultural taxation, and commercial law as it relates to agriculture. As the program continues to mature, greater emphasis will be placed on research in theoretical and policy-oriented agricultural law. Research will become increasingly important and concentrated in terms of subject matter.

Quantitative and Research Methods

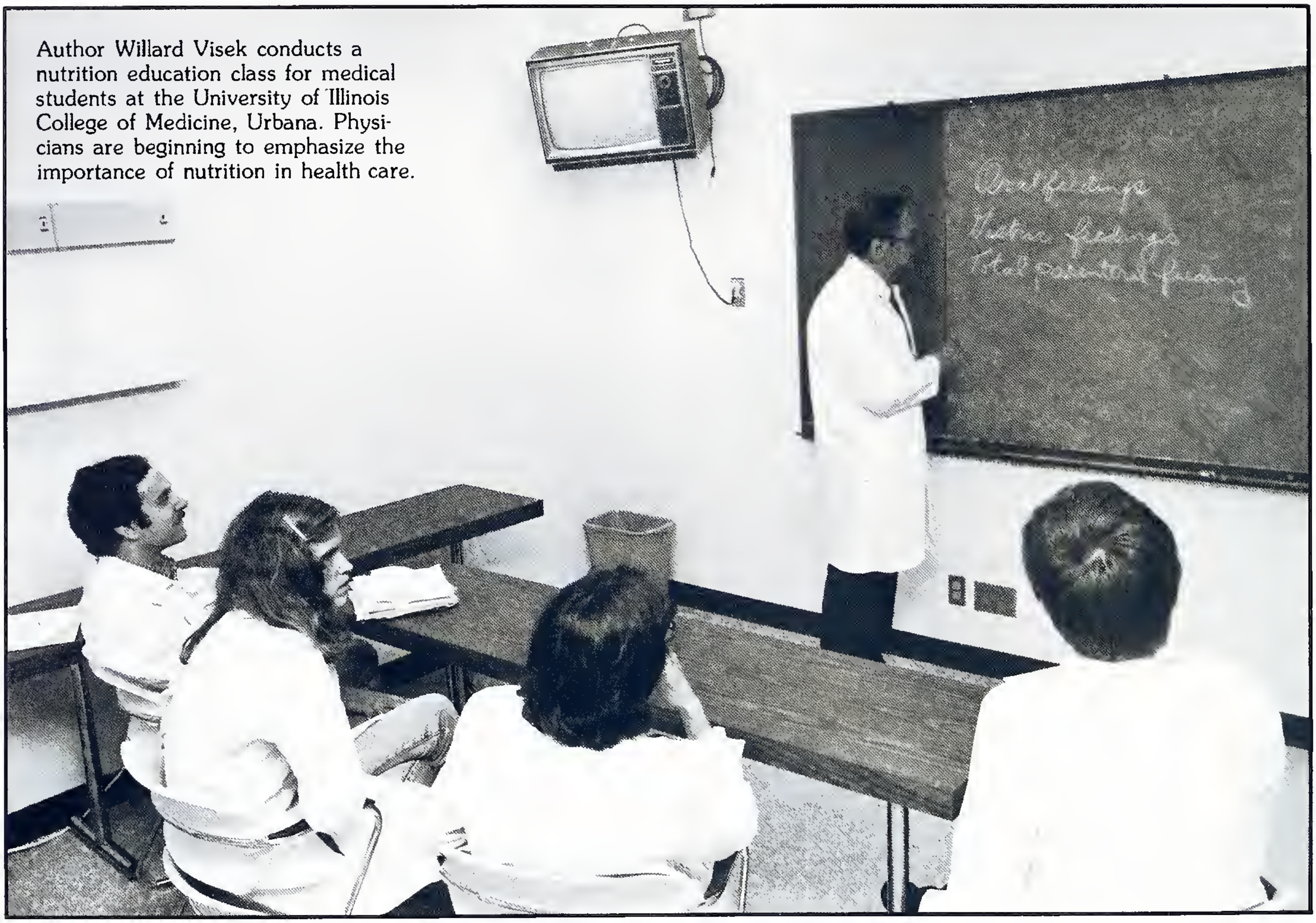
In the past quarter century, social scientists have invested significant resources to improve methods for doing research. New and improved techniques and tools reduce research costs and expand the range of problems that can be investigated. Improvements have been made in econometric and sociometric methods for estimating production, cost and demand relationships; for identifying the incidences and effects of structural changes in the farm and rural nonfarm sectors; and for price forecasting. Programming methods were improved to provide better estimates of sector responses to market and policy changes and firm-household responses to changes in commodity and capital markets and in technological opportunities.

In years to come, econometric models will be improved still more, especially for analyzing time series of data for forecasting prices and testing hypotheses implied by models of how economic agents form expectations about the future. Intertemporal optimization models that accommodate random variables will improve studies of capital acquisition and financial control, as well as the aggregative effects of technological changes arising from the biophysical sciences.

The various socioeconomic research areas are highly complementary. For example, research in commercial agriculture contributes to models that improve public as well as private policy decisions. Research on problems of rural communities and in natural resources improves the environment not only of commercial agriculture, but also of the general public. All of these research areas affect and are affected by legal as well as social sanctions brought to bear in the public interest. And finally, all affect and are affected by international events, now that international commodity and financial markets are increasingly integrated.

Chester B. Baker, professor of agricultural economics

Tractor size today compared with twenty-five years ago is an indication of the phenomenal growth in commercial agriculture. As the enterprise grows, increasingly sophisticated research is necessary to study related socioeconomic problems.



Author Willard Visek conducts a nutrition education class for medical students at the University of Illinois College of Medicine, Urbana. Physicians are beginning to emphasize the importance of nutrition in health care.

Human Nutrition and Health

Willard J. Visek

During the 4th century B.C., the Greek physician Hippocrates claimed that illness could be understood only if patients were seen in relation to the environment. He was especially concerned with diet. Despite the modern ring to his ideas, Hippocrates had little understanding of nutrition. He believed, for example, that each foodstuff contained a single essential factor and that one particular food would cure a specific disease; his opinion was groundless.

Early nutritional knowledge. Our views of food and its composition remained virtually stagnant for more than 2000 years. Then, during the middle of the 18th century, the young science of chemistry showed that foods are complicated mixtures of chemicals. The chemoanalytic approach, which followed in the 19th century, went several steps farther and divided the nutrients in food into four categories: proteins, carbohydrates, fats, and minerals. This concept was so dominant that chemists developed standardized procedures for comparing foods and feeds on the basis of these components.

Although incomplete, this information was useful for delineating the essentials of animal nutrition, thus preparing the way for dramatic advances in human nutrition. These achievements in agricultural chemistry were reinforced by the establishment of experiment stations, which

enhanced agricultural research in general. The University of Illinois was a leader in this development.

Animal nutrition. For many years chemical composition continued to be used as the basis for comparing the nutritive value of various feeds. With this information alone, some believed they could prescribe the most profitable husbandry and cropping practices for scientifically feeding farm animals. It didn't take experiment station researchers long to find out, though, that straight chemical analysis was not enough for predicting whether formulated rations would be adequate in practice.

Fortunately, scientists observed that rations containing single feeds or purified ingredients were linked with specific diseases or syndromes that could be produced or cured by diet. In 1912 Casmir Funk, after reviewing the history of what came to be known as deficiency diseases, introduced the idea that additional, special substances are essential in the diet. The substances he was referring to are now known as vitamins. Funk's observations ushered in intense efforts to discover, isolate, and synthesize these accessory food factors.

Reaching its peak in the 1930s and early 1940s, the so-called vitamin era was also devoted to determining which amino acids are essential and in what quantities. The University of Illinois was the site of major contributions, these by W. C. Rose and his students, who led the way in establishing criteria for identifying the essential amino acids. The capstone of Rose's work was the discovery of threonine, thus completing the list of amino acids needed to sustain life.

Although the necessary vitamins were probably all identified in the 1940s, the list of essential trace minerals continues to grow. The quantities needed to meet dietary requirements are minuscule — often only one part per million or less. We therefore had to wait for the development in the last two or three decades of highly sensitive analytical and experimental techniques before finally being able to pin down the dietary requirements for some of the trace minerals.

Nutrition and medicine. These dazzling successes led many to believe that the deficiency diseases had been conquered. Unwarranted complacency followed. Even today, many people seem convinced that deficiency diseases afflict only the children in poor nations. Much to our dismay, however, the past decade has shown that protein-calorie malnutrition occurs in a high percentage of hospitalized adults and the elderly in the United States. With this realization, medical schools have begun emphasizing nutrition education in the training of physicians. Attention to nutritional needs is steadily becoming an integral part of our health care system.

A recent advance of major proportions in medical care is the total intravenous feeding of patients. This technology evolved from the findings of S. Dudrick, a surgeon doing research at the University of Pennsylvania. In the late 1960s, Dudrick and his coworkers found that humans can survive for many months when fed entirely by vein. Responding favorably to this form of alimentation, many patients with once fatal conditions, such as severe injuries that prevent eating, can now return to normal life. Used successfully in thousands of cases, this technique allows precise control of the nutrient supply and has given nutritional therapy much visibility in medical practice.

The control provided in total intravenous feeding proved valuable in another way: it enabled us to verify in humans the need for certain nutrients that had been indicated, but not conclusively demonstrated, by animal studies. We now know that animals and humans must have about fifty chemically identifiable substances to meet their nutritional needs. Determinations of this nature are based largely on biologic assays, which measure the responses of living organisms to specific substances.

During the past twenty-five years, researchers have intensified their work on the complex etiology of heart disease and how diet may be a causal factor. Epidemiological evidence continues to mount, showing that the environment, including life style and diet, is a major determinant of cancer incidence. In the United States and other developed countries, heart disease accounts for 50 percent and cancer for 20 percent of all deaths. Manifested mainly in the later decades of life, these diseases occur more frequently in countries that enjoy a high standard of living.

Resulting from a number of interacting variables, heart disease and cancer cannot be prevented by supplying or controlling a single factor, as in the case of deficiency diseases. However, new methods arising from the efforts of the entire scientific world are fostering rapid progress.

Despite strenuous challenges to the hypothesis that links diet to these diseases, a great many consumers are beginning to make significant changes in the foods they eat. Agriculture, and particularly the food industry, will need to anticipate adjustments that will become necessary in production and processing programs as the complex etiologies of heart disease and cancer unfold.

New knowledge will continue to flow from routine scientific efforts, but equally important advances will arise serendipitously. For instance, in 1973 Japanese scientists discovered that one of their experimental male rabbits had a genetic defect that raised its cholesterol to ten times the normal level. Progeny of this single ancestor are now providing animal models for resolving heretofore unanswerable questions about cholesterol and heart disease.

These studies have led to techniques that can be employed in human patients with similar hereditary conditions. Furthermore, drugs have been developed to hasten progress in treating heart disease and faulty cholesterol metabolism. Such advances will become increasingly common as our understanding of biological processes at the molecular level grows.

To keep new knowledge in perspective, agricultural scientists will have to use and understand sophisticated research methodology that may appear unrelated to traditional agricultural research and practice. Highly tangible and economically important results are bound to follow, just as they did with the development of hybrid seed corn, control of livestock reproduction, artificial breeding, and applications of modern statistical methods.

Nutritional research. While the nutrients essential for humans and animals were being determined, dramatic advances in food production and processing also occurred. For example, after World War II the Illinois Agricultural Experiment Station led the way in demonstrating that simple-stomached animals will produce efficiently when fed soybean protein combined with corn. Ninety percent of U.S. pork is now produced from this combination. Arising from research completed here in the early 1960s, this change has boosted soybeans to a major industry worldwide.

New biochemical knowledge about enzymes has also had a major effect on the market value of certain crops. An outstanding example is the use of immobilized enzymes to produce fructose syrup from cornstarch. The technology involved adheres enzymes to a chemically made matrix so that part of the glucose in cornstarch is converted to fructose. A much sweeter and cheaper fructose syrup is the result. The industries that produce sugar from sugar cane and sugar beets have been severely disrupted because they cannot compete effectively with fructose in the marketplace.

This same technology has already made it possible to lower the production cost of specific amino acids used in foods and in medicine. Moreover, the technology may eventually produce lactose-free milk for people who cannot tolerate lactose, the natural sugar contained in milk. Similar technology has been used to treat whey, which is left after cheese making and has undesirable environmental effects.

Another potential advantage of immobilized enzyme technology may be in the elimination of the undesirable taste of heat-treated milk. Milk so treated could be stored without refrigeration, thus lowering storage and distribution costs. Immobilized enzymes have already been used to remove unpleasant tastes and odors from other foods, to manufacture flavor enhancers, and to produce essential oils whose supply from countries in politically sensitive areas of the world may be in jeopardy.

These and other forms of recently developed biotechnology are already supplying hormones for improving the production and growth of food-producing animals. Genetic engineering applied to agriculture is expected to represent a $100 billion industry by the year 2000.

During recent decades, the general public has begun looking seriously at nutritional health and food quality. The communications media have discussed these tropics at length, but misinformation and confusion sometimes result. This state of affairs is apt to continue, because issues related to food encompass so many national and international groups, among them, farmers, food processors, regulatory agencies, health care professionals, and environmental protection organizations. Future gains in human and animal nutrition to match those of the past must, of necessity, deal with all segments of society.

Willard J. Visek, professor of nutrition and metabolism, University of Illinois College of Medicine at Urbana-Champaign and the Department of Food Science

Views on Agriculture

The Strength of a Nation

by John E. Cribbet

During my long tenure at the University of Illinois, I have had the fortunate opportunity to witness first-hand the exciting development of numerous teaching, research, and service programs on campus. With sustained public interest and support and through the efforts of our distinguished faculties, the Urbana-Champaign campus has become one of the nation's leading institutions of higher education, ranking among the world's great universities. It is a resource of inestimable value for the social and economic well-being of the state and nation. Although the stature of the campus is based on many factors, the Illinois Agricultural Experiment Station has played a strong role in establishing this reputation for excellence.

Agriculture, the largest business activity in the United States, is of central importance to the economic vitality of Illinois. Thanks primarily to the contributions of research, the past quarter of a century has witnessed unprecedented advances in American agriculture. As the human population continues to grow, natural resources will have to be exploited to the fullest to meet the world population's ever-expanding needs. These demands point to an even more important role for agricultural research in the years ahead. To meet future needs, we will have to increase not only the levels of food production, but also our research efforts in such areas as chemical feedstocks, agricultural high technology, and new energy sources.

Since its establishment nearly a century ago, the Experiment Station has been at the forefront of significant advances in agricultural research and development. The Illinois Station conducted, for example, the first experiments in genetic improvement of corn, leading to the development of hybrid corn and dramatic increases in yields. The Station has also conducted world-recognized research on soybean production and the use of soybeans for widespread human consumption.

The Station's research activities and contributions — both basic and applied — have touched nearly every dimension of agriculture, including animal and crop production and protection, human nutrition, rural development, soil and water conservation, and the uses of agricultural products. The benefits have been dispersed widely to the public, and many of the research findings have been transferred to developing countries as well. As a stimulant to economic growth in less developed nations, these transfers are directly related to the creation of new foreign markets for American agricultural products.

Agricultural experimentation in the United States has a long and distinguished record of achievement and service; the Illinois Station will continue to be an important part of that record. In the decades ahead, a vigorous, coordinated, national approach will be more important than ever in meeting the changing demands of American agriculture. Strong support for research, conducted through the Illinois Station and its counterparts across the country, will remain a vital element in sustaining our national strength and well-being.

John E. Cribbet, chancellor, University of Illinois at Urbana-Champaign

by M. B. Russell

Science and the technology generated by it are powerful agents for economic and social change. No sector of the economy has demonstrated this fact more clearly than agriculture, which has realized dramatic increases in crop yields and livestock productivity since World War II. This achievement has resulted from advances in our understanding of the basic physical, biological, and socioeconomic processes that are constantly interacting in the agricultural production system.

Agriculture's rapid utilization of new scientific findings is no accident. It springs from the wisdom of those far-sighted individuals who, in 1888, created the publicly funded state experiment stations for the purpose of applying the scientific method to agricultural problems. The stations in most instances were closely linked to the newly created colleges of agriculture and, after 1912, to the publicly supported state extension services.

This unique institutional arrangement allows agricultural scientists to associate closely with teachers and researchers from all disciplines and with extension personnel who stay abreast of problems in agricultural production and rural living. Thus, experiment station scientists form a bridge between research and the agricultural production system.

As the units of that system continue to grow in size and specialization, they become increasingly interdependent on the expanding set of public and private organizations serving them and more intimately linked into the total socioeconomic fabric of the nation and the world. Changes in the technology of agricultural production may therefore cause far-reaching ripple effects throughout the agricultural sector and beyond it. Conversely, innovations in other sectors may affect agriculture.

During the past three decades, science-based agricultural technology has been recognized worldwide as a powerful catalyst for economic development. Many nations having agrarian economies are now establishing teaching-research-extension triads of their own to stimulate food production, rural welfare, and national economic growth. New international research institutes, created and funded by donor agencies, are also striving to increase food production in the underdeveloped parts of the world.

If these efforts are to succeed, agricultural scientists must be trained well enough to see how advances in their parent disciplines relate to the total production system. They must also monitor the work of other agricultural and applied research units and judge whether the system might be favorably or adversely affected by their findings.

It is imperative that our understanding of the agricultural production system and the factors governing it continues to grow. Only then will we be able to meet global food needs and improve the living standards of rural and urban people throughout the world.

M. B. Russell, director of the Illinois Agricultural Experiment Station, 1962 through 1969

by Harold B. Steele

Lawmakers who drafted the 1888 bill authorizing the nation's agricultural experiment stations had the good judgment to know that scientists in the laboratory needed to reach farmers in the field. Thus an entire section of the act dealt with communications. For a quarter of a century, *Illinois Research* has carried the message of the Illinois Agricultural Experiment Station in the spirit outlined almost one hundred years ago.

I wish I could say that farmers have always been as farsighted about the value of basic research. But I would be bending history a bit to make such a claim. The fact is, many American farmers were skeptical at first about the benefits of scientific agriculture. European farmers, on the other hand, often seemed eager to embrace these new ways. In addition, tough times on the farm have often prompted some farmers to suggest that the United States should curtail research programs. These critics said that research simply contributes to agriculture's surplus.

Happily, the Illinois Farm Bureau did not share this view. People in the state's largest farm organization have always accepted the demands of change and the opportunities of progress. The vast majority of farmers were not content with horse and harness. They knew that soybeans could be used for more than hay.

By 1959, when *Illinois Research* first appeared, the contributions of the nations's experiment stations had helped boost Illinois corn yields to 64 bushels per acre and total production to more than 500 million bushels. Soybean production had climbed from almost nothing to 125 million bushels. Since 1959, per-acre corn yields have more than doubled, and total soybean production has almost tripled.

by Floyd S. Ingersoll

The Farm Bureau has often criticized the federal government for attempting to do things it ought not do. An outstanding exception was the creation of a nationwide system of tax-supported research for agriculture. It works because the administrators of the stations are responsive to local needs. Although financed in part by a federal authority, the system was never dominated by that authority. This uniquely American system has proved to be the best structure for producing economic and scientific dividends in a democratic society.

Going far beyond commodity production, research now addresses challenges to be faced by farmers in the year 2000. For example, we will need to know more about handling the personal and social problems of farmers. Adapting to the demands of a tense life in a tough business will be an increasingly important concern. The future will reward the best managers, those who have the techniques to make the wisest use of expensive farm inputs. The Illinois Experiment Station will help produce those techniques. Finally, the urgent need to conserve our most important resource, the soil of Illinois, will dominate the thinking of farmers and scientists for the next generation.

The challenges of the future recall a classic achievement — the conquest of polio in the 1950s. Mechanics and engineers attacked the problem by designing a better iron lung. Scientists developed a vaccine instead. The latter is the kind of thinking that will come from the Illinois Agricultural Experiment Station.

Harold B. Steele, president of the Illinois Farm Bureau, 1970 through 1983

Cooperation has been excellent between the Illinois Agricultural Experiment Station and the seed industry during the past twenty-five years. Under the able leadership of the Department of Agronomy, real progress has been made. Yields for soybeans, corn, wheat, oats, and alfalfa have increased so steadily that one Illinois farmer can now feed a hundred people. As a rule, Experiment Station findings have been disseminated and accepted rapidly, primarily because of the close interaction among the Cooperative Extension Service, the seed industry, and farmers.

The agricultural success story has been brought about to a large degree by superior developmental research. From the farmer's point of view, progress can be measured by developments that benefit every-day farming operations. Typical examples include the availability of superior varieties such as 'Williams' soybeans, the B73 corn inbred, 'Caldwell' wheat, and 'Ogle' oats. Farmers have also benefited from recommendations for fertilizer and herbicide use and for cultural practices. During recent decades, applied as well as basic research has been financed by the public; the results have been made available at little or no cost to individuals.

In considering the next twenty-five years of progress, we will see many changes in the way the Experiment Station, seed industry, and farmers relate to one another. Tremendous pressure for increased basic research will be put on the Station as a result of recent developments in genetic engineering and other basic studies. For Station administrators, however, financing these projects is problematic. Public financing is simply not increasing enough. The research environment of the Experiment Station provides many advantages with its technically trained personnel and initial funding for laboratories and equipment through Food for Century III. The Station could offer much more if it weren't for acute shortages in professional staffing and the special equipment required for work with DNA, gene splicing and recombination, regeneration of plants from single cells, and so forth.

To participate adequately in this exciting new field of genetic engineering, our Experiment Station must turn to private industry for adequate financing. Substantial contracts have already been negotiated with two major firms, namely, Agrigenetics Research Corporation and Standard Oil of Ohio. True, contracts such as these will call for some restrictions upon the release of material, but Illinois seed dealers and farmers will have an opportunity to participate.

Without doubt, the next twenty-five years will be the most productive in the history of the Illinois Agricultural Experiment Station, but cooperation among all interested parties will have to become even stronger than it is today. With supplemental financing from private sources the Station will make great strides in basic research. Private enterprise will see a spectacular increase in its own developmental research, aided by biotechnical discoveries from the Station. Useful end products will continue to flow from basic research and from the education of plant and animal breeders and other agriculturalists. Everyone — Illinois farmers and consumers alike — will benefit.

Floyd S. Ingersoll, executive vice president, Illinois Foundation Seed, Inc.

In Progress

Good news for pepper growers

Bell peppers, one of the most popular vegetables, grow best in a loamy, well drained soil in full sunlight. The ideal temperature for plant growth and fruit production is 80°F (27°C). These conditions do not guarantee high yields, however.

Above 90°F (33°C), and especially if the humidity is low, more young buds and blossoms than usual drop from the plant. Pepper yields are also influenced by nitrogen. For example, nitrogen applied at high rates before planting may result in excessive vegetative growth and low pepper yields. Nitrogen applied after planting, however, does not necessarily lead to similar problems, as some growers fear.

For four years John Gerber and Walter Splittstoesser in the Department of Horticulture have been studying the influence of sidedressed nitrogen on peppers grown in several soil types. The nitrogen was applied two months after seedlings were transplanted.

Gerber says that the number of peppers per plant did not decrease with nitrogen application, even at rates as high as 600 pounds per acre (672 kg/ha). The rate at which fruit matured was unaffected by the nitrogen levels used in the study. Fruit size was similar on all locations with all nitrogen rates.

By harvest time, 47 percent of the flower buds, 57 percent of the flowers, and 31 percent of the set fruit had dropped off. This finding suggests that many more flowers are produced than the plants can maintain and develop. The percentage (2.28) of nitrogen in the leaf tissue did not differ significantly among treatments or soil types, nor did high rates of sidedressed nitrogen result in decreased yields or delayed maturation of peppers.

Growers can rest assured: using sidedressed nitrogen on pepper plants will not reduce yields, Gerber says. Moreover, plants sidedressed with nitrogen grow larger than those without it, thus shading the fruit and reducing sunscald. The larger plants also have higher yields because they produce fruit longer into the fall.

Recommended rates of nitrogen are 100 pounds per acre (112 kg/ha) broadcast preplant and 50 pounds (56 kg/ha) sidedressed two months after transplanting. On sandy soils, an additional 25 pounds (28 kg/ha) may be sidedressed after the first harvest.

Microcomputers for agriculture

The low-cost microprocessor — the "brain" of the personal computer — has created some fundamental changes in the way we use computers. "In a sense, these remarkable devices have democratized computing by putting computing power into the hands of many individuals," says Thomas Knecht, head of the Office of Agricultural Publications.

The small size and relatively low cost of these computers have made it possible to automate information processing in areas where computerization would have been too expensive or cumbersome before. Scientists and educators in the College of Agriculture have been using computers ever since the early days of mainframe computing. In recent years, however, the College has taken advantage of microelectronic technology to improve its internal efficiency and its ability to serve the public, Knecht says.

The processing of words is a striking example of how this technology is used. The College now has 5 shared word-processing systems with 45 work stations located in 11 different units. (Several other units have stand-alone processors.) This system is being used very successfully in preparing a wide variety of typewritten materials. It is especially effective for long reports and proposals that normally go through many drafts before they are issued. The system saves a substantial amount of retyping and allows one department to transmit documents electronically to another.

To meet the farmers' computing needs, the Extension Service has equipped 9 regional offices and 11 campus departmental offices with personal computers. In addition, 29 county Extension offices have obtained microcomputers, and 14 have systems on order. Five special application programs for agriculture have been prepared and released to the county offices; 19 more are under development. The computer systems will be used by county Extension staff in their work with farmers whose management programs can benefit from computerized analyses.

The College has opened a laboratory equipped with 22 microcomputers for use in resident teaching. At least 3 departments are now using the laboratory for student course work. The College is also automating student records, research management information, addressing, collection of data from experiments, and the enrollment of members in the 4-H program.

Recognizing the immense opportunities that the "information age" offers for agriculture, the College is developing a proposal to guide its expansion in this area, Knecht says. The provisions will help us offer sound leadership in the computerization of Illinois agriculture.

Photos by David Williams

Two years ago the site of Bergen Garden in Chicago was a concrete wasteland on top of a parking garage (above). Today it blooms with flowers, trees, and groundcovers planted in a "soil" of modified hardwood bark (below). The garden encompasses 58,000 square feet. The pond is 6 inches deep. One goal of the project was to find an environmentally suitable way to dispose of unwanted bark from wood-processing industries.

Rooftop oasis on a concrete desert

Building a garden on the roof of a parking structure is about as easy as coaxing flowers and trees to grow in the Sahara. Yet a Chicago contractor, a designer, and University of Illinois scientists have done just that.

The biggest problem that they had to solve was finding a growing medium dense enough to support some 50 trees and 30,000 plants but light weight enough to meet load limitations of the building. After testing several soil substitutes, David Williams and colleagues in the Department of Horticulture recommended a modified, composted, hardwood bark used by Illinois nurseries. The medium was the only one that met the engineering, economic, and cultural specifications of the project.

A mere two years after it was begun in the spring of 1982, Bergen Garden in Hyde Park on Lake Michigan is beginning to thrive with plantings of pachysandra and ivy, daylilies, lilacs, cotoneaster, juniper, and viburnum nestled beneath a canopy of oak, birch, and flowering crab apples. Dozens of planting boxes contain petunias, Shasta and Alaskan daisies, lobelia, ageratum, and plantain lilies.

The garden is the culmination of efforts by College of Agriculture researchers to develop an environmentally sound method for disposing of the bark, Williams says. The project is an innovative way of meeting air and water emission regulations established by the federal government in the 1960s for utilizing industrial wastes.

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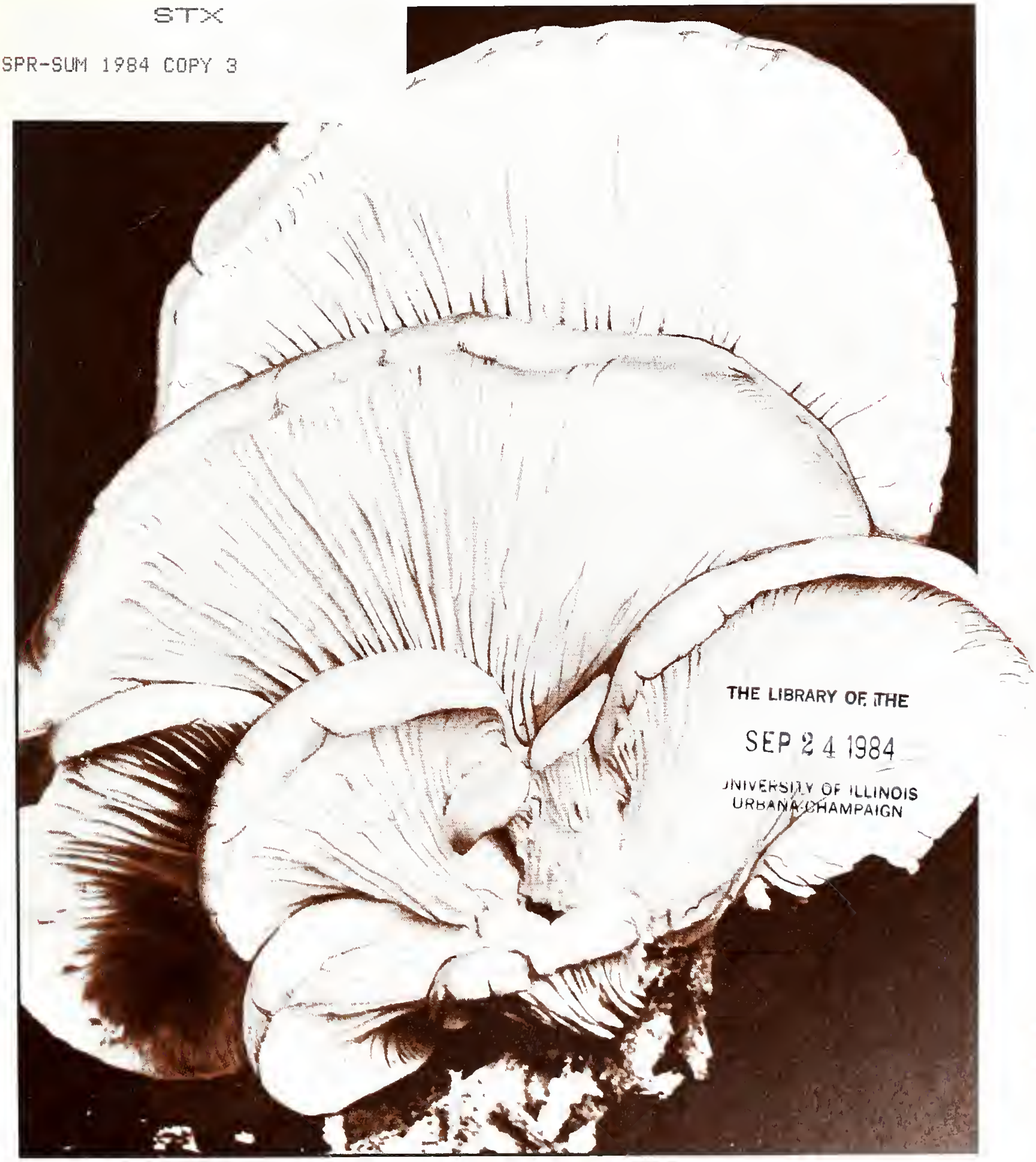
Illinois Research

Spring 1984

New products from field and forest crops

Illinois Research

Agricultural Experiment Station
Spring/Summer 1984



College of Agriculture, University of Illinois at Urbana-Champaign, Volume 26, Numbers 2/3

1984 - Directions - 1994

The Biomass Age

Consumers are anxiously eyeing the erratic supply and mounting cost of petroleum because it provides energy for our homes and cars. Few people realize, though, that countless other products — chemicals, plastics, and paint to name only three — are also derived from petroleum. In recent years, however, the steadily rising price tags on petroleum-based products used at home and in industry have been sending out an urgent message: the time has come to find alternatives to petroleum. Biomass from field and forest crops may one day provide those alternatives.

In this issue of *Illinois Research* we explore the potential for many new and unique uses of field and forest crops. Not only the grain and fiber but also the residues and by-products can become important sources of energy and chemicals in the future. Postharvest technology is the key to expanding the use of these renewable resources. The concept of adding value to them is especially salient if we are to improve the economic status of both producers and manufacturers. We have every reason to believe that the raw materials produced in Illinois can be processed and turned into new products right here in the state. The surge of commercial activity would unquestionably stimulate the Illinois economy. The value-added concept applies equally to foreign exports.

Traditionally, most research monies have been slated for improving yields. Research for this purpose must continue, for it will eventually pay big dividends by lowering the cost of raw materials. Expanded uses of grain and fiber crops will add an entirely new dimension to our current markets. But funding for research in post-harvest technology must increase accordingly. A partnership between industry, government, and public institutions of higher education is being developed to ensure that we achieve this goal.

Renewable resources offer a tremendous opportunity for meeting many of society's energy and chemical needs at affordable prices. The Illinois Agricultural Experiment Station is in a strong position to provide the basic research and trained personnel needed. Given adequate funding, we have the means at hand for reducing our dependence on foreign oil and for expanding our farm and forest economy.

Gary L. Rolfe, head, Department of Forestry

The Cover

The edible oyster mushroom (*Pleurotus ostreatus*) is a wood-rot fungus found in moist, wooded areas. It and other agents are being used experimentally to break down field and forest residues into many usable substances (see pages 8 and 9).

"At a time unlike any in the past, we must envision the future."

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Contents

Letters

To the readers:

We are using this double issue of *Illinois Research* (spring/summer) to bring publication time back on schedule. Unavoidable production delays in past issues have made this adjustment necessary.

In future issues, *Illinois Research* will contain articles on the family; international agriculture; animal production and well-being; the weather and its effects on humans, plants, and animals; and the computerization and mechanization of agriculture. Selected by the editorial board, these themes give contributors an opportunity to discuss fundamental and applied research as it relates to the needs of Illinois citizens and to our international interests.

The "In Progress" column will continue to supplement each theme with brief reports of other research and information about the College of Agriculture. The "Update" column will be presented at irregular intervals as developments in agricultural and food policy warrant. Suggested readings on a particular theme will be listed from time to time in the "Publications" section. Letters to the editor are always welcome.

Sheila A. Ryan, editor

Address communications to Editor, Illinois Research, University of Illinois at Urbana-Champaign, 47 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801.

Please limit letters to 250 words.

The Language of Biomass Technology: A Glossary

The terminology related to biomass conversion is borrowed from several sciences. Some terms that may prove difficult for nonspecialist readers are defined here. The definitions are intended to clarify the terms as they are used in this issue of *Illinois Research.*

acetone — flammable liquid used as a solvent for substances composed of large molecules

aromatic compounds — chemicals such as benzene consisting of carbon and hydrogen in a ring structure; used as intermediates in making herbicides, medicines, and other products

bagasse — woody residue remaining after sugar is extracted from sugar cane

biodegradable — capable of being broken down into harmless products by organisms in the environment

biomass — plant materials used as a source of energy and chemicals

carbohydrates — various sugars, starches, and celluloses formed by green plants

cellulose — fibrous material such as cotton and paper

chemical feedstock — any raw material that can be used to produce chemical products

chemical intermediate — chemical used to make other chemicals

corn gluten — tenacious, elastic protein substance from corn; makes an excellent animal feed

critical path method — standard management procedure for scheduling the stages in an operation, starting with the most critical

ethanol — an alcohol derived mainly from sugar and starch by fermentation; used as an octane-enhancer in gasoline

extractives — materials withdrawn from biomass by physical or chemical processes

furfural — oily liquid used in the manufacture of plastics and as a solvent

game theory — analysis of a situation involving conflicting interests (as in business) in terms of gains and losses among opposing players

germ — the part of a seed from which the plant develops

glucose — a sugar occurring widely in nature; known as corn sugar

heavy metal — metal of a high specific gravity, e.g., mercury

hydrocarbon — organic compound containing only carbon and hydrogen, obtained from fossil fuels

hydrophobic — lacking affinity for water

lignin — complex binding material that helps form the cell wall of plants

lignocellulose — plant material consisting of lignin, cellulose, hemicellulose, and other matter

lipids — fats and oils

membrane — thin filter material that allows small molecules to pass, usually under pressure

methanol — an alcohol derived from wood; used as a solvent, antifreeze, or chemical intermediate; poisonous

octane-enhancer — additive such as ethanol that improves the performance of gasoline

oleic — referring to an unsaturated fatty acid found in natural fats and oils

polymer — large molecule composed of many (poly) repeated subunits; e.g., many ethylene units linked together form polyethylene

polymerize — to link organic subunits into a polymer

polyurethane — polymer used in flexible and rigid foams and in resins

sawlog — log of suitable size for sawing into lumber

solvent — a liquid substance that dissolves other compounds without undergoing chemical change

sulfurization — process of combining or treating with sulfur

surfactant — detergent or other agent added to water to break up oil into droplets and hold them in suspension

system science — method of analyzing, testing, synthesizing, and operating a system

terpenes — hydrocarbons found in oils from certain plants; used as solvents

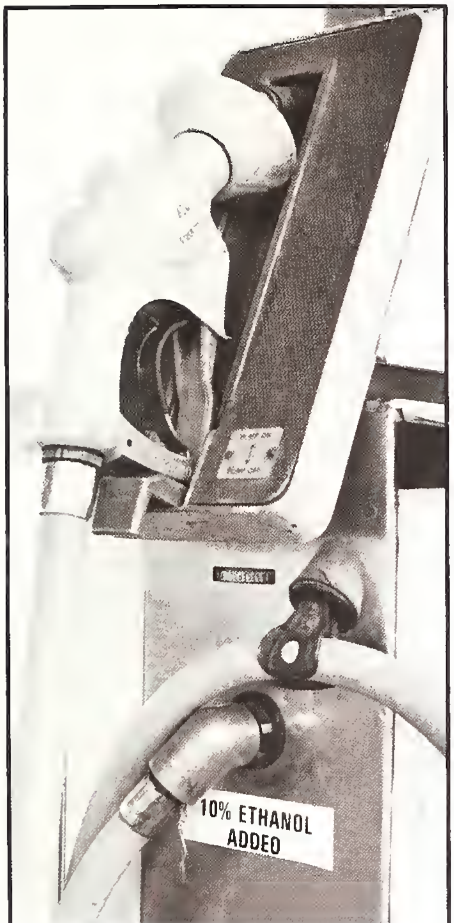
tung oil — obtained from the seeds of tung trees; used in quick-drying varnishes and paints

volatile — readily vaporized at relatively low temperatures

wet milling — process of milling (as of corn) that involves soaking first in water or other fluid

Waste Not, Want Not: Adding Value to Forest and Field Crops

Arthur J. Siedler and Richard R. Hahn



Ethanol, one of many nonfood products derived from field crops, is now being produced on a relatively large scale in some areas of the state. Added to gasoline as an octane-enhancer, ethanol can help reduce our dependence on petroleum.

Money may not grow on trees and corn plants, but plastics, synthetic rubber, and insulation materials do. These and a host of other products are there for the taking. At present, however, trees are harvested almost solely for lumber, firewood, and paper. The fate of field crops is similarly predictable: most are used to feed humans and livestock.

In recent years, the scientific imagination has been piqued by advances in technology and the soaring cost of petroleum-based products. As a consequence, researchers have begun to explore the great potential for unique uses of field and forest crops. Residues and the by-products generated from processing are also being scrutinized for ways to add value to them. As things now stand, some of these by-products are a nuisance, causing problems for waste disposal and pollution control.

Food versus nonfood products. The $300 billion food industry is the major user of agricultural crops. One of the largest segments of the U.S. economy, the food industry employs 1.7 million workers and adds a value of more than $80 billion to the raw materials supplied by agriculture. But domestic food consumption on a per capita basis has reached a plateau. Further growth in the industry will therefore stem from population increases in this country, from value added to raw materials, and from services rendered.

In contrast to U.S. markets, demand for food products on international markets continues to rise. These markets will account for any significant increases in the direct use of agricultural crops for food. Although steadily rising, the increases probably won't be large during the next decade.

Converting field and forest crops to nonfood products seems to be the best bet for expanding old markets or creating new ones. The predicted shortfall in nonrenewable sources of energy makes this possibility especially attractive. Raw materials from fields and forests might also become major sources of chemical feedstocks.

The value-added concept. Adding value to the by-products (or coproducts as they are now called) of processing is another vital part of the picture. After wet milling, for example, the coproducts are combined into corn feeds and sold to recover nearly half of the corn costs. Even sunflower seed hulls can be put to good use by burning them to produce most of the energy needed for processing the seeds.

Disposing of cheese whey, effluents from paper mills, and similar materials poses more of a problem. Large amounts of water must be removed to keep shipping costs down, but the energy required for removal is expensive. The use of new membrane technology to remove water at low energy costs may eventually improve the economics of these materials.

High fructose corn syrup (HFCS), a major achievement in corn utilization, has helped consumers by stimulating competition among domesti-

cally produced sweeteners. Each year the average American consumes 125 pounds (57 kg) of various sweeteners. More than a third of this amount is derived from corn, most of it in the form of HFCS.

The huge increase in wet milling to produce fructose has in turn generated large amounts of corn gluten protein. Combined with the fibrous parts of corn, it is used primarily in animal rations. As a coproduct its economic importance depends upon the nutrient value and its price relative to other feed ingredients. Significant quantities of corn gluten feed are exported every year. Since income from it is important, we can't afford to discard it. Other uses for corn gluten would increase its value still more, but so far the potential has not been fully exploited.

Economic questions. Thus far we can't make any informed predictions about the economic effects of advances in postharvest technologies. Economists have not yet dug into studying the potential of new products and markets and how they might affect demand for raw materials. Undoubtedly, though, the demand created by new enterprises will interfere to some extent with old, established demands.

All the consequences should be assessed to aid in smooth economic transitions. The impact that high fructose corn syrup had on the demand for sugar cane and sugar beets is an example of ripple effects that may follow a breakthrough. When industries compete, the consumer is of course the real winner.

Reducing the cost of raw materials should not be overlooked as a means of increasing their utilization. If we were able to double or triple productivity without increasing production costs per acre, the unit price would then be low enough to compete effectively in new markets. If, for example, corn could be reduced to one dollar per bushel, it would be a very cost-effective raw material for ethanol or other energy substitutes.

Two major approaches to increasing the utilization of field and forest crops seem clear. First, raw materials should be made more economically attractive by adding value to them. Second, they should be produced at a cost that encourages several industries to compete for them.

Postharvest technology. Applying science to get the greatest possible mileage out of agricultural products is often referred to as postharvest technology. The economy depends on this critical component, which links farm products to consumer needs. Postharvest technology provides U.S. consumers with an inexpensive, varied, and wholesome food supply second to none in the world. It also provides paper, wood products, chemicals, adhesives, ethanol, and other nonfood products.

The development of postharvest technology depends upon three essential ingredients:

- A pool of basic research knowledge, which is the foundation for creative technology
- Trained scientists with the vision to apply this knowledge in meeting consumer needs and desires
- Industrial exploitation that offers a return on investment to encourage the development of new technologies

Public institutions, particularly land-grant universities, are uniquely suited for doing the basic research and supplying a cadre of technically trained personnel.

Funding. Traditionally, research and development related to postharvest technology have been funded by those industries concerned with particular products. State and federal funding for this purpose has been a small percentage of government's total research budget. Currently, only about 10 percent of the budget for the U.S. Department of Agriculture and land-grant institutions is slated for postharvest and marketing economics research.

We must not allow public funding for basic research in fields important to postharvest technology to deteriorate. In fact, basic research must now be supported more vigorously than ever before. To this end, a new partnership is being forged among industry, government, and institutions of higher learning, particularly those in the land-grant system.

If postharvest technology is to keep pace with national and world needs, additional investments must be made to support the necessary fundamental research and development. Renewable resources from field and forest can be fully exploited only by having the basic knowledge available for developing the required technologies. The work must be interdisciplinary if the results are to be used in manufacturing new and more valuable products. Cooperation among academic communities, government, and industry is essential.

Arthur J. Siedler, professor of food science; Richard R. Hahn, vice president for research and development, A. E. Staley Manufacturing Company

Renewable Sources of Chemicals

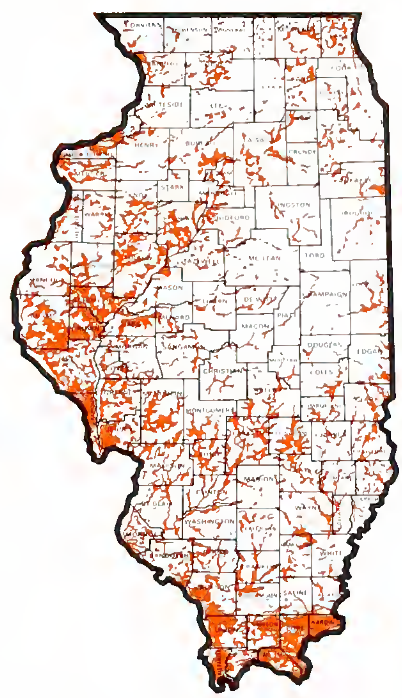
Gary L. Rolfe and Kenneth J. Moore

The chemical industry is taking a critical look at its future sources of feedstocks and energy. For the moment, petroleum and natural gas are the main sources, but they are no longer the bargain they once were and the supply is at times unreliable. The price tag on these hydrocarbons is expected to outstrip the inflation rate, thus pressuring the industry to shift to other sources.

Biomass and coal, the most likely alternatives, will certainly be important feedstock and energy sources in the future. Coal in particular is sure to be used in large quantities. For the long run, however, the best all-around feedstock is biomass because, unlike fossil fuels, the supply is renewable and can be expanded to meet demand. Used as a fuel, biomass is also relatively clean.

Plants and trees naturally produce a great variety of chemicals and compounds such as rubber, resins, terpenes, carbohydrates (including starch, hemicellulose, and cellulose), proteins, fats, waxes, and lignin (Fig. 1). From the standpoint of the chemical industry, glucose and its polymers are perhaps the most valuable product of photosynthesis. A choice source of energy, glucose can be converted by microbes into hundreds of different chemicals.

An even greater variety of chemicals will become available as genetic engineering, recombinant DNA, mutant selection, and gene splicing pave the way for more efficient production with higher yields. Up to the present, research efforts have gone into improving plants for food. Similar efforts must now be directed towards producing biomass for energy, chemical feedstocks, and other nonfood products.



Orange areas show Illinois forest lands.

Forest crops. Our forest lands benefit the state in many ways: they protect the soil from erosion, enhance water quality, serve as windbreaks, provide grazing and recreational areas, and beautify the landscape. But Illinois residents tend to overlook the potential commercial value of the state's forests. Carefully managed, these forests along with marginal lands planted to trees could supply enough woody biomass to meet an impressive portion of our needs for wood, energy, and chemical feedstocks.

Illinois forests cover approximately 4 million acres (1.6 million ha) of forest land; another 2 million acres (800,000 ha) of marginal land should be under some sort of permanent cover. About 65 percent of the forest land is in the southern third of the state, but western and northwestern Illinois also claim considerable forested acreage. Hardwoods dominate, with 97 percent of the forests classified as oak-hickory or elm-ash-cottonwood. Much of the wood is too low in quality to be suited for lumber, however.

The land nevertheless presents opportunities for producing 125 cubic feet of lumber per acre (8.65 cubic m/ha) per year. More than 0.5 million acres (200,000 ha) fall into the highest productivity class of U.S. forest lands. Except for Ohio, Illinois contains more land in this class than does any other midwestern or lake state. Some 40 percent of the total is classified as highly productive and could produce at least 85 cubic feet of lumber per acre (5.88 cubic m/ha) per year. Clearly, the yield potential is great. The point bears repeating: under good management our forests could supply a significant amount of the wood, energy, and chemical feedstocks needed in Illinois.

The quantity of wood produced on these lands varies widely: the poorest land yields only about 0.25 dry ton per acre (0.56 metric ton/ha, MT/ha) per year and the best up to 3 tons (6.7 MT) under traditional sawlog management. On the average, the potential for sawlog production is near 1.5 dry tons (3.4 MT) per year. Under the best of conditions, however, production could easily reach 4 or 4.5 dry tons (9 or 10 MT) with an intensive management system using close spacings. Even with woody biomass yields averaging only 3 to 4 tons per acre (6.7 to 9 MT/ha), Illinois forest lands could annually produce a sizable quantity of wood material for pulp, reconstituted wood products, chemicals, and energy.

Historically, woody biomass has been a prime source of chemicals. Distillation of hardwoods produced not only charcoal, but also acids, methanol, and acetone. Naval stores including turpentine, rosin, pitch, and tar were obtained from softwoods. Fermentation produced butanol, ethanol, and many other organic chemicals from sugars and starches.

Then around the turn of the century, coal and petroleum both began to replace wood as the prime source of organic chemicals. Following World War II, petroleum became the dominant feedstock in the chemical industry, forcing wood and coal out of that market. Once again, though, we need a variety of feedstocks to ensure continued production of needed chemicals at affordable prices.

Wood is rapidly returning as one of these feedstocks. New technology

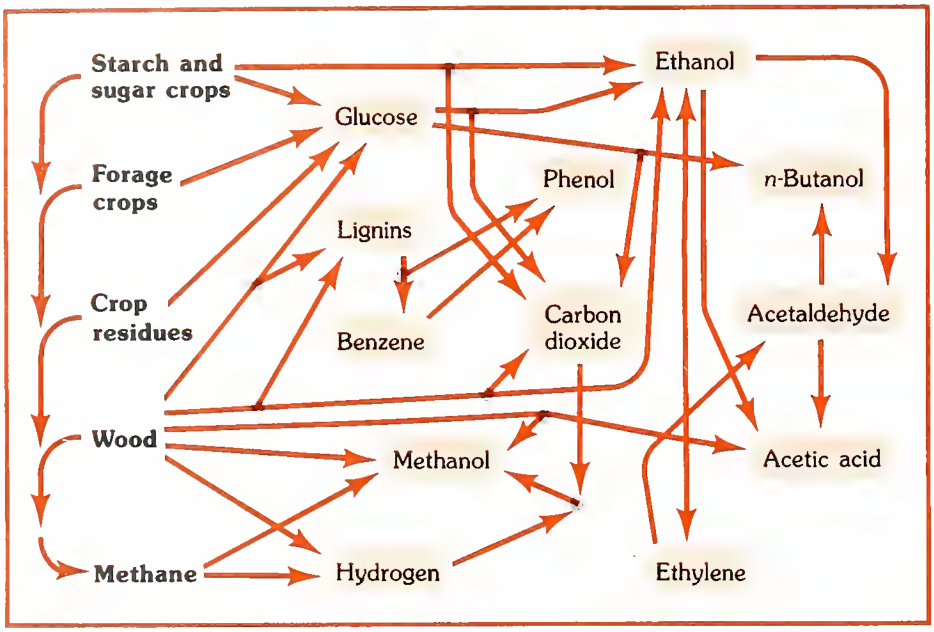


Fig. 1. Some of the many compounds and chemicals, most of them intermediates, produced from field crops and trees. ◉ = By-product

is developing better systems for breaking down the lignins and cellulose in wood into the compounds that form them. When these techniques become commercially feasible, we will have an extremely cheap feedstock that could eventually nudge petroleum out of much of the chemical industry. The general pathways and the products derived from wood and other biomass are summarized in Figure 1.

Although sawlog management systems are not appropriate for this purpose, the material remaining after harvest is suitable. These residues — up to 60 percent of the total wood production — are attractive to wood conversion industries. Unfortunately, less than half of the residues can be removed economically. Furthermore, leaving them in place, especially on low quality sites and steep slopes, has considerable merit because residues protect the soil and return nutrients to it.

An alternative management system, that of biomass production using short rotations and close spacings, offers excellent opportunity for producing wood for chemicals. Our recommended system includes fast-growing species such as sycamore, hybrid poplar, silver maple, black locust, and autumn olive. All of these species produce large quantities of biomass quickly when planted 18 or 24 inches (46 or 61 cm) apart in 30-inch (76 cm) rows. In rows of this width, the crop can be cultivated mechanically, thereby lowering establishment costs.

The optimum rotation time for this planting combination varies from 3 to 5 years, depending on the site. After that time an annual yield can be generated with a planned cutting cycle. Since these species produce well from stump sprouts, one planting provides biomass for 2 to 5 rotations. Once established, the system generates 3 to 5 dry tons per acre (6.7 to 11 MT/ha) per year on most sites.

In addition to fast-growing tree species, many woody shrubs contain large quantities of extractives and are thus potentially useful as feedstocks. Autumn olive, sassafras, staghorn sumac, and similar species produce well and are high in total extractives. In recent work, we evaluated several woody shrubs for total biomass yield and extractives content. Preliminary results are shown in Table 1.

Overall, woody biomass in the form of forest residues, trees, and shrubs shows excellent promise for becoming an important chemical feedstock. Given the quality of our forest lands, Illinois can be a leader.

Field crops. Our agricultural lands also show great promise for producing biomass. The major chemical feedstocks derived from crops grown in Illinois are starch and lignocellulose. Corn, sorghum grain, and wheat are abundant sources of starch; each bushel contains about 34 pounds (15 kg). In 1982 more than 25 million tons (22.7 million metric tons, MMT) of starch were produced in Illinois from these crops.

Some of the starch, particularly cornstarch, is already being used to manufacture adhesives, laundry starches, polyurethane foams and plastics, and other useful products derived from starch-based chemicals. However, most of the starch grains are used for animal feed or human food. It is therefore unlikely that large quantities of grain will be diverted from these markets to the chemical industry.

Since starch grains are already spoken for by established markets, the favored source of chemical feedstocks will probably be lignocellulosic materials. These materials have a twofold use: first, they yield glucose and other sugars to serve as substrate for fermentative processes and, second, they contain lignin, from which a variety of aromatic compounds can be synthesized (Fig. 1).

The residues remaining after grain harvest are excellent sources of lignocellulosic biomass. Each year an estimated 40 million tons (36.3 MMT) of crop residues are generated in the state. The stover, cobs, and other residues from the corn crop alone account for nearly 52 percent of the total. Soybean residues account for another 40 percent, and residues from small grains and sorghum make up most of the remainder.

Because crop residues can be collected and handled much like forage crops, most of the machinery required for harvest is already available. From an environmental standpoint, however, removing all residues has disadvantages. A substantial proportion should therefore be left where it is to maintain soil stability and productivity. The amount that could be safely harvested is still open to discussion.

Table 1. ***Average Yield and Alcohol-Benzene Extractives in Woody Shrubs, Dixon Springs Agricultural Center, Illinois***

Species	Dry tons/ acre per year (MT/ha)[a]	Alcohol-benzene extractives[b] Wood	Leaves
		percent	
Autumn olive	4.30 (9.64)	5.7	9.4
Coral berry	0.57 (1.28)	5.5	13.9
Elderberry	2.06 (4.62)	4.3	11.7
Honeysuckle	1.50 (3.36)	6.1	16.3
Sassafras	1.98 (4.44)	6.5	8.9
Silver maple	3.79 (8.50)	7.7	31.4
Smooth sumac	2.27 (5.09)	4.7	23.2
Spicebush	1.47 (2.29)	3.1	16.3
Staghorn sumac	3.13 (7.02)	8.3	27.6

[a]Wood yield only; 18 inches x 30 inches (46 x 76 cm) spacing between plants.
[b]Alcohol-benzene extractives is a reliable test of chemical extractives potential.

Table 2. ***Biomass Yield Potential of Various Crops When Raised in Southern Illinois***

Annuals	Dry tons/ acre per year (MT/ha)	Perennials	Dry tons/ acre per year (MT/ha)
Tropical forage sorghum	20 (44.8)	Eastern gamagrass	9 (20.2)
Sweet sorghum	12 (26.9)	Switchgrass	7 (15.7)
Silage corn	10 (22.4)	Big bluestem	7 (15.7)
Sorghum-sudangrass hybrids	6 (13.5)	Indiangrass	6 (13.5)
Sudangrass	5 (11.2)	Reed canarygrass	6 (13.5)
Pearl millet	5 (11.2)	Tall fescue	5 (11.2)
		Orchardgrass	5 (11.2)

In a recent report, the Office of Technology Assessment conservatively estimated that 9 million tons (8.2 MMT) of Illinois crop residues could be used annually as chemical feedstock. Only one other state has more residues available, placing Illinois in a good position to become a leader in developing this underutilized resource.

Currently Illinois has about 4.2 million acres (1.7 million ha) of improved pasture, hay, and silage crops. More intensive management, primarily involving improved fertility practices, could easily increase the yield by as much as 2 tons per acre (4.5 MT/ha). The surplus of 8.4 million tons (7.6 MMT) per year thus produced would then be available as a biomass resource. Only minimal changes would be needed in forage production practices.

Forage crops are customarily managed to obtain an optimum yield of high quality forage. For this reason they are usually harvested at early stages of maturity, after which the digestibility and protein value begin to decline rapidly. Dry matter continues to accumulate, however, with maximum yields occurring at full maturity. At this stage, the amount of lignocellulose is at its peak.

With relatively minor changes in current cutting practices, forage crops could be efficiently managed for dual use as a chemical feedstock and as an animal feed. Cool-season grasses such as orchardgrass and tall fescue can produce optimum biomass yields under a two-cutting management scheme, according to research findings. However, some evidence indicates that this practice may reduce stand longevity. Warm-season grasses would probably be harvested only once a year after frost.

Estimated biomass yields from various forage crops are presented in Table 2. Based on the results of field trials in southern Illinois and Indiana, these estimates reflect management practices designed to achieve maximum biomass production. Tropical sorghum has higher yields of dry matter than does any other crop tested, but the plants grow 20 feet (6.1 m) tall, are very dense, and are not easily harvested. Sweet sorghum, more appropriately classified as a sugar crop rather than a forage crop, yields up to 4 tons of sugar per acre (9 MT/ha) and produces large amounts of lignocellulose as well. It is an excellent candidate for biomass production in Illinois.

Any additional acreage brought into production for biomass crops is likely to be only marginally suited to row crops. Illinois has an estimated 2 million acres (800,000 ha) of such land. Typical marginal lands are erosive and require special tillage practices for row crop production. Well suited to these soils, perennial forage crops can produce high yields of biomass while preventing erosion and maintaining soil productivity. Another advantage of perennials is that they produce for several years from a single planting, thereby reducing the costs and risks associated with crop establishment.

Biomass may ultimately be the all-around feedstock because it is renewable and can be expanded to meet demand. Marginal agricultural lands in particular show excellent promise for producing woody biomass in short-rotation systems, crop residues, and forage crops. Our energy and chemicals of the future may well come from plants grown here in Illinois.

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The Quest for an Efficient Conversion Process

Poo Chow and Marvin P. Steinberg

The largest renewable resource in the world today is the material known as lignocellulose. Some common sources are sawdust, wood chips, and other woody by-products of lumber manufacturing, and nonwoody agricultural by-products such as corn cobs, sugar cane bagasse, and stalks from rice, wheat, corn, and cotton. Only a small fraction of the amount available is collected and used each year. If lignocellulosic materials could be efficiently degraded, however, they could serve as animal feeds and as sources of many of the chemical products that are currently derived from crude petroleum, a nonrenewable resource.

The technology of conversion has been slow to develop because lignocellulose is a stable material that resists chemical and biological attack. Lignocellulose is composed of cellulose, hemicellulose, and lignin. Cellulose, which makes up about 50 percent of plant fiber, is composed of glucose molecules (six-carbon sugars). Hemicellulose, which makes up about 25 percent of plant fiber, is a mixture of hexoses (six-carbon sugars with a different construction from that of glucose) and pentoses (five-carbon sugars). The remaining 25 percent is lignin, a complex binding material the structure of which is still not completely understood. As a natural resin or binding agent in plant fiber, lignin tends to encase the other two components and therefore is a barrier to converting plant fiber to more useful products.

The first step in any conversion process is pretreating the lignocellulosic material to disrupt the bonds among the three components. Strong chemicals such as sulfuric acid and caustic soda can be used as disrupting agents. Paper manufacturers have traditionally used them to separate the lignin from the cellulose that is needed for paper. But this process, though relatively easy, is expensive. The strong chemicals, which are costly, are constantly being used up, and the pretreatment also requires the use of expensive equipment. For these reasons, researchers have been trying to find pretreatment procedures that would require less energy and expense.

Pentose 5-carbon sugar	**Hexose** 6-carbon sugar (noncrystal form)	**Glucose** 6-carbon sugar (crystal form)
C HO	C HO	C HO
|	|	|
$(C\ HOH)_3$	C HOH	$(C\ HOH)_4$
|	|	|
$C\ H_2OH$	$(C\ HOH)_3$	$C\ H_2OH$
	|	
	$C\ H_2OH$	

The sugar molecules in lignocellulose must be separated from each other before they can be converted to other substances. The most versatile sugar is glucose, which is essentially a hexose because it has six carbons. The pentoses, which have only five carbons, are not as versatile as glucose. The hardwoods in Illinois have a large quantity of pentose sugars. See box page 10.

Agricultural residues. One such attempt is the current research on converting agricultural by-products into animal feeds. The two crop residues most frequently mentioned as readily available sources of biomass are corn cobs and bagasse, the fibrous material left over from sugar manufacturing. Since these residues have about the same composition as grass, they should be able to serve as ruminant feeds. However, like grass, they are digested slowly and so have a very low feed efficiency. If they could be pretreated, their feed value could be much improved.

Many different treatments of agricultural residues have been tried, but all of them are expensive. For example, it is possible to apply extremely high steam pressure to crop residues. When this pressure is released, the explosive action effectively separates the components and makes the lignin water-soluble so that it can be washed out. Further treatment with a weak solution of caustic soda will then separate the cellulose and hemicellulose. Unfortunately, the application of high pressure requires very expensive equipment.

A possible alternative route is now being explored with fungi. The residue is first boiled in water with a small amount of caustic to improve its wettability, and then it is inoculated with the white rot fungus *Pleurotus ostreatus* (the oyster mushroom). The fungus begins digesting the residue; as it grows, it also converts some of the nonprotein nitrogen that is present in the waste into protein, thus increasing the food value of the waste. In other words, the fungus performs the same func-

Drawing by Lenore Gray

We can solve many problems if we let nature do our work for us. The oyster mushroom (left) is a wood-rotting fungus that can be put to work in the laboratory — in this case breaking down a mixture of sawdust and oats (right). In the lab, as in nature, the invisible roots digest the material, and the visible fruiting bodies rise to disperse spores. (The abnormal shape of the mushroom in the jar is caused by irregular humidity.)
Photo courtesy of T. Kaneshiro; see article in Dev. Ind. Microbiol. 18(1977): 591-597.

tion as the first stomach of the cow.

The use of a natural degrading agent such as this white rot fungus should be inexpensive because only a small amount of caustic is needed and the fungus does all the work. Since this fungus is an edible mushroom that is highly regarded by people in Eastern Europe, it has an additional advantage in that it can also be used as food. Its fruiting bodies, or caps, could conceivably be harvested as human food at the same time that its digesting portions in the residue are being used as ruminant feed.

However, the use of a fungus, like many other methods, is not yet problem-free. This particular fungus grows slowly, and unless the residue is sterilized, contaminants outgrow the inoculum. Sterilizing, which would involve the use of steam, would reintroduce an expense. There are some indications that a small addition of another by-product such as wheat bran will increase the growth rate. In this and all such attempts, progress will depend on the use of knowledge from many fields.

Sawdust, a woody by-product of lumber manufacturing, and corn crop residue, a nonwoody agricultural by-product, are just two of the many abundant materials that are available for conversion to useful materials.

Woody residues. Research is also being done on converting woody materials such as sawdust and wood chips to products that are now derived from petroleum. Again, some more economical variation of the pretreatment with strong chemicals must be found. A full understanding of the challenge necessitates some explanation of the end-products that can be derived from the three different components of lignocellulose.

Lignin, the first stumbling block in any conversion, is in itself valuable as a binding agent for wood products and as a stabilizer for substances such as concrete. It is also a potential source of many chemicals that are currently derived from petroleum. For example, lignin can be further treated to yield phenol, a chemical used in the manufacture of adhesives, wood preservatives, and plastic. Some paper companies are extracting lignin now for this purpose. Lignin is also a source of hydrocarbons (important fuels) and of many useful chemical intermediates. For example, it is a possible source of benzene, which is used in no-lead gasoline and is now in great demand by the petroleum industry.

Most of the processes used to convert lignin into these products are still expensive because they involve the use of heat and pressure. Conversion of lignin will be feasible on a large scale only if the price of petroleum becomes prohibitive or if the cost of conversion can be reduced. Paper companies still use most of their lignin residues as fuel. The only derivative of lignin that has been used for a long time is vanillin (artificial vanilla), which is produced by oxidizing the lignin obtained as a by-product of paper manufacturing.

Uses for Cellulose and Hemicellulose

One of the most valuable products of cellulose and hemicellulose is glucose. Glucose can be readily fermented to yield ethanol, which can be used as a gasoline additive or converted to chemicals such as ethylene. Ethylene has a wide variety of uses. For example, it can be polymerized into polyethylene, the material that is used in the manufacture of products such as plastic film. It can also be used with benzene in the production of polystyrene, the foam insulating material; ethylene glycol, which is used as an antifreeze; and vinyl chloride, which is used in plastic manufacturing for products such as overlays on particle board. Many chemicals and polymers now made from propylene, a petroleum derivative, could be made from ethylene if it could be economically produced from lignocellulosic materials.

The ethanol that is derived from glucose also yields several other important chemicals besides ethylene. Butadiene, used in the production of synthetic rubber, is one. Other potential major derivatives are acetaldehyde, acetic acid, and acrylonitrile.

Glucose is obtained mainly from cellulose. Since it is a six-carbon, or hexose, sugar, the conversion processes listed below under "From Hexoses" are basically those used to convert cellulose. Hemicellulose, on the other hand, yields both hexoses and pentoses. Pentose sugars contain only five carbons and are more difficult to ferment than glucose.

Most of the woody residues in the eastern United States, including Illinois, are from deciduous wood. Since the hemicellulose component of this wood is largely pentose sugars, the conversion of this kind of lignocellulose is a primary challenge for areas such as Illinois.

Products obtainable from pentoses and hexoses

From Pentoses *(5-carbon sugars)*

Fermentation → yeast (for production of vitamins, protein, and fat)
Dehydration → furfural (for plastic manufacturing)
Hydrogenation → polyols (chemical solvents and intermediates)
Crystallization → xylose (ruminant feed)

From Hexoses *(6-carbon sugars)*

Fermentation → alcohol (ethyl-, butyl-, isopropyl-)
polyols (glycerol; ethylene glycol, an antifreeze; propylene glycol)
ketones (such as acetone for making explosives, nail polish, and many other products)
acids (acetic-, lactic-, butyric-)
Dehydration and hydrolysis → hydroxymethylfurfural, levulinic acid (chemical intermediates)
Hydrogenation → glycerol, other alcohols
Crystallization → glucose (for alcohol production; also a human nutrient and an excellent animal feed)

Cellulose and hemicellulose are the components of fibrous materials that contain sugars. Since those sugars are bonded together in long chains, the next step after pretreatment is to break apart those bonds, through a process called hydrolysis, to produce individual sugar molecules. Once the molecules are separated, they can be treated in various ways to yield a wide array of end-products (see box).

The primary difficulty lies in hydrolyzing the bonds without using too much energy and creating too much expense and waste. Once lignin is gone, a weaker, less expensive agent such as hydrochloric acid (30 percent concentration) can be used. Hydrolysis with this weaker acid is fast and complete; however, it still requires a large amount of cooking energy and the use of expensive equipment, and it also breaks down some valuable sugars.

An alternative to this approach is being explored with enzymes produced by microbes. This approach would require less energy and cause less pollution because, like the use of fungi, it would involve no cooking. It would also produce a higher yield because it would not break down any liberated sugars. Unfortunately, the enzymes must be painstakingly separated from living cells and then purified, so they are expensive at the present time. Therefore the use of enzymes to break apart cellulose and hemicellulose, while it holds great promise, is still a reality only in the laboratory.

Poo Chow, professor of forestry, and Marvin P. Steinberg, professor of food engineering

New Uses for Starch and Oils

Everett H. Pryde and Felix H. Otey

Biomass, agricultural residues and by-products, and crops themselves must eventually provide many of the raw materials now supplied by petroleum. Starch, fats, and oils have already made notable contributions to socioeconomic needs and probably will contribute greater shares in the future.

In the discussion that follows, we will briefly review some of the research on starch and lipids and the implications for industry. The research reported here was conducted at the U.S. Department of Agriculture's Northern Regional Research Center.

Fig. 1. A laundry bag that will dissolve in water has been developed using starch as the base. In hospitals, bags full of soiled linens can be placed unopened into washing machines. Laundry workers are thereby protected from contaminated materials.

Starch. Starch-based industrial products are kinder to the environment and may be easier on the pocketbook than are some products made from petroleum. A prime candidate for replacing certain petrochemicals, cornstarch is available at low cost and can be converted readily into many useful chemicals and plastics. In 1979 the six major cereal grain crops in the United States contained 470 billion pounds (213 million metric tons, MMT) of starch. Only 2 to 3 percent of this starch is customarily isolated, however, and less than one percent is used for industrial purposes. We are now searching for products and processes that will raise this percentage.

Polyols. In the past several years we have developed and extensively evaluated a way of producing polyols from starch. (Polyols are the basic materials used to make oil-based paints, detergents, and rigid polyurethane insulation.) In pilot-plant studies, polyols were used in conventional products. For example, polyurethane foam was made flame resistant by the three-stage reaction of starch-derived glucose with other chemicals.

Recently the A. E. Staley Manufacturing Company came on-stream with a pilot-plant process for making a polyol from cornstarch. The company's ultimate aim is to produce a line of corn-derived organic chemicals for foams, adhesives, paints, and detergents. These chemicals may prove to be a 5-billion-pound (2.2 MMT) market annually.

Plastics. We now have techniques that will allow us to substitute starch for significant amounts of petrochemicals used in manufacturing plastics. Industry is attracted to starch because it is renewable and products made from it are water soluble and biodegradable in varying degrees. In one commercial process, for example, starch partly replaces petroleum-derived polyvinyl alcohol to produce water-soluble laundry bags. These bags are desirable because hospital laundry workers don't have to handle the contaminated clothing collected in them (Fig. 1).

Agriculture, too, can look forward to biodegradable plastics made from combinations of starch and plastic resins. Mulch film is a good example of how they will be beneficial. Farmers now use some 60 million pounds (27,000 MT) of petroleum-derived polyethylene mulch film. Boosting yields by as much as 350 percent, the film helps to retain soil moisture, prevent loss of added fertilizer, and keep down weed growth. A biodegradable film would save the $100 per acre that it now costs to remove and dispose of nondegradable film. Farmers have also expressed interest in dozens of other new biodegradable plastic materials for planting, growing, and harvesting crops.

Rubber. Starch for forming powdered rubber may be a boon to industries that manufacture rubber articles. The key is in using starch to encase the droplets of rubber in crude latex. Compared with conventional slab rubber, the powdered form saves time and energy because it can be handled directly by injection-molding machines, thus eliminat-

ing the high-energy mixing needed for processing slab rubber. Starch can also be incorporated in processed rubber to fill the same function as carbon black.

Waste-water purification. Traces of heavy metals can be removed effectively from waste water by ISX (insoluble starch xanthate), a starch material that contains sulfur. About thirty companies have licenses to use or produce the patented product, and at least twenty-five metal-plating firms have installed the ISX treatment to meet U.S. Environmental Protection Agency requirements. This technology increases markets for agricultural products and at the same time solves a pollution problem by permitting reuse of process water.

Encapsulated pesticides. We now have the technology to encapsulate a range of pesticides in small cells within a biodegradable starch matrix. Released at a controlled rate, a pesticide can be confined to a targeted area, thereby reducing negative environmental effects. Farmers who handle these products receive considerably less exposure to the toxins in them. In field tests of encapsulated herbicides, cooperating scientists at several universities have shown that weed control is greatly improved.

Starch graft copolymers. Certain petroleum materials can be chemically attached to starch. Our basic research on the resulting graft copolymers has yielded new products with many potential uses. Super Slurper, the first major commercial product resulting from this study, has received worldwide attention. As the name suggests, Super Slurper absorbs fluids by as much as many hundred times its own weight, an especially valuable property for industrial applications.

Super Slurper is used in commercial products to absorb urine, blood, perspiration, and other body fluids; to control forest fires; and to establish seedlings and transplants for agriculture. It is also used as an industrial thickening agent. In addition to removing water from fuel alcohol mixtures, Super Slurper may eventually have many other agricultural, industrial, and medical uses. Graft copolymers are also being evaluated for making plastics.

Lipids. Every year, U.S. industry produces 20 billion pounds (9 MMT) of fats and oils. Half of this amount is consumed in edible oil products, a quarter goes into nonfood products, and a quarter is exported. In spite of this large supply, we annually import about 2 billion pounds (900,000 MT) of vegetable oils such as coconut, palm, castor, and tung oils. Roughly a third of this amount is slated for use in industrial products.

Substitutes for many of these imported oils could be grown in the United States to help improve our trade balance. At present, fats and oils contribute only 2 percent to the total synthetic organic chemical industry. This contribution could be increased substantially by using high yielding oilseed crops to provide feedstocks for industry. Domestically produced feedstocks would help conserve our fossil resources.

Fats and oils compete more heavily with petrochemicals for some markets than for others. For example, 40 percent of all coatings and 45 percent of all surfactants are based on fats and oils, compared with only 15 percent of all plastic additives. These and similar markets can be expected to grow as petroleum products become scarcer and more costly. Already 6 to 8 percent of the 9 billion pounds (4.1 MMT) of soybean oil used annually in the United States is funneled into nonfood industries. Several new products made from vegetable oils are of commercial interest.

Coatings. One way to cut down on the large amount of solvents polluting the atmosphere may be to use water-dispersible resins for paint binders. In exploratory research, resins suitable for solventless coatings that are baked onto metal were made from derivatives of soybean oil treated with ozone. Other derivatives were used for making water-dispersible resins. Seventy to 80 percent of the material in these resins is derived from vegetable oils and 20 to 30 percent from petrochemicals. The flexible, adherent coatings made from them dry rapidly at room temperature without the usual metallic driers.

Engineering thermoplastics. These materials include nylons that are cast and formed into gears, gear housings, and the like. A nylonlike material can be made from soybean oil (Fig. 2), although a high-oleic sunflower or similar vegetable oil would be more efficient. Absorbing less moisture than the nylon now used for clothing, this experimental material keeps its shape and does not conduct electricity under moist conditions. An even more hydrophobic experimental nylon can be made from oilseed crops such as crambe and rapeseed. In many ways, these nylons are comparable to commercially available nylons, but they have a lower melting point, are slightly less dense, and absorb less moisture. All of these properties have advantages for users.

Lubricants. Synthesis gas (a mixture of carbon monoxide and hydrogen) and other building blocks used

Fig. 2. A bag of soybeans dangles from nylon 9 single-stranded thread. Suitable for fishing line, the thread is special because it was made from soybean oil.

in the petrochemical industry can be combined with vegetable oils to make lubricants. One derivative of soybean oil can be used at temperatures as low as −94°F (−70°C). Other derivatives have been prepared to serve as substitutes for sperm whale oil and as lubricants for continuous casting of steel. Excellent lubricants have also been made from linseed oil subjected to alkali treatment. Sulfurization of soybean oil is yet another method under investigation. From this work we have found some important leads for developing high-pressure lubricant additives for use in automatic transmission fluids.

Plasticizers. A commercial plasticizer for vinyl plastics has become a widespread environmental contaminant. Eventually, however, several vegetable-oil-based plasticizers may take its place. These compounds will probably be biodegradable and nontoxic, but as yet the properties have not been assessed.

Excellent low-temperature plasticizers with exceptional light stability have been made from crambe oil. The unusually low volatility of products from the reaction of synthesis gas with soybean oil may be an advantage in plasticizers for the automotive industry. Used in upholstery, they won't form a film on the windshield as the more volatile plasticizers now in use tend to do.

Oilseed crops. Many plants have been screened for their economic potential as oilseed crops. Some of the more promising ones include Abyssinian kale (*Crambe abyssinica*), pictured in Figure 3, and meadowfoam (*Limnanthes* sp.) for their long-chain fatty acids; cigar flower (*Cuphea* sp.) for its short-chain fatty acids; bladderpod (*Lesquerella* sp.) for its hydroxy fatty acids; and ironweed (*Vernonia* sp.) for its epoxy fatty acids.

Vernonia galamensis seed oil has been evaluated for its paint-forming properties, which include excellent flexibility, adhesion to substrate, and chemical and solvent resistance. Industry needs the short-chain fatty acids found in *Cuphea* seed oils for making the new synthetic ester lubricants, soaps, and shampoos.

These and many other uses for starch and oils are now available. Some products have already achieved industrial success; others simply await appropriate technology transfer and implementation. Still others, particularly the vegetable-oil derivatives, need more favorable competition with petrochemicals, an opportunity that will assuredly occur as our petroleum resources become depleted.

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Fig. 3. Crambe (*Crambe abyssinica*) is a potential oilseed crop for Illinois.

Different System Needed for Raw Materials

Donnell R. Hunt

A burst of prosperity may be in store for agriculture. In the not-too-distant future, opportunities should begin to arise for providing new raw materials to the industrial sections of our nation. If chemical-based industries are to continue producing the wonderful array of products our consumer-oriented society has grown accustomed to, feedstocks from agriculture will have to be introduced to replace high-priced petroleum, natural gas, and mineral deposits. The potential is there, but considerable planning is necessary first.

Organic chemists have already shown that agricultural residues and coproducts can serve as raw materials for many industrial products. For example, paper has been made from straw, insulation board from corn stalks, furfural and face powder from corn cobs, and paint and plastics from vegetable oils. Furthermore, all plant materials can be burned either directly in furnaces or indirectly after being changed to gases, oils, or simple alcohols.

The substitution of renewable carbohydrate compounds for many nonrenewable hydrocarbons augurs well for agricultural products in industry. If the substitution is made, though, it will cause great changes in the nation's agricultural, commercial, and industrial systems.

For thousands of years, agriculture was a self-sufficient way of life. Supplying their own labor, animal power, and tools, farm families planned principally for their own needs. Food was stored and cloth woven on the farm, while residues and wastes were recycled at the point of production. Subsistence farmers seldom interacted with the small, nonagricultural part of society except when transporting and marketing occasional surplus products.

As urbanization increased, so did agriculture's role as an industry rather than as a way of life. Farmers now sell what they produce to processing industries that supply society with a wide variety of food and nonfood products. The urban sector in turn supplies farmers with energy, fuels, fertilizers, and equipment, as well as with food and clothing. Today, American agriculture is an integral part of a giant life-support system.

A system has many components interacting for the sake of a common goal; a change in one component affects the whole. To be stable, a system must operate without sudden and erratic changes in output despite variation in input. But stability occurs only if disturbances can be compensated for within the system.

Without proper planning, the proposed substitution of agricultural raw materials for petroleum could destabilize the nation's life-support system. If the problem is approached with the insights provided by system science, however, the number of false starts inherent in randomly adopting new technology can be reduced.

The food supply system. Various diagrammatic and mathematical methods are available for analyzing a system. The elements of a simple agricultural supply subsystem of the nation's life-support system are presented in Figure 1. Farm products flow from widely dispersed production sites, through concentrated processing operations, and then to scattered consumer markets. Transportation, so essential to the system, is indicated by the lines connecting the elements. Since consumer demand tends to be constant with time, storage facilities — surge chambers for the flow — must be included to accommodate the seasonal flow of agricultural production.

Working freely, our food supply system is probably the most efficient in the world. Nevertheless, the existing food system cannot be expected to absorb a new raw material supply system. Even if grains, fruits, and vegetables, in addition to residues, were to be used as raw materials for industry, a separate system would be needed for health safety reasons.

Different processes and materials-handling equipment will be required for providing industry with cellulosic plant parts. Imagine, for example, the changes in the wheat supply system if suddenly wheat straw were to be burned to provide process power. In that event, the wheat head should remain attached to the straw stem until threshed at the flour mill. Currently, bagasse is burned to provide power for extracting sugar from cane. An important difference between sugar and wheat should be noted, however. Extraction of sugar from sugar cane is not a simple process and therefore the whole stalk must be carried to the relatively efficient central mill. Wheat kernels, on the other hand, are fairly easy to separate from straw. An analysis could produce the startling recommendation that flour should be milled on the farm, where the straw could be burned at low cost. All aspects of a system must be examined before choosing the most effective operation.

System solutions. Mathematical modeling and simulation allow us to take much of the guesswork out of analyzing and designing systems. The procedures used help predict the following:

- Performance of the system at a desired production level
- Sensitivity of the system to its components
- Compatability of the components and subsystems
- Stability of the system when subjected to a disturbance

The various techniques developed are available as digital computer programs. We can now evaluate how well a system might perform by using linear and nonlinear programming, dynamic programming, game theory, and critical path methods. These programs are much more efficient than the expensive and time-consuming procedure of establishing a system and then monitoring its performance. Regardless of the method used, however, it is critical to have accurate predictions of the

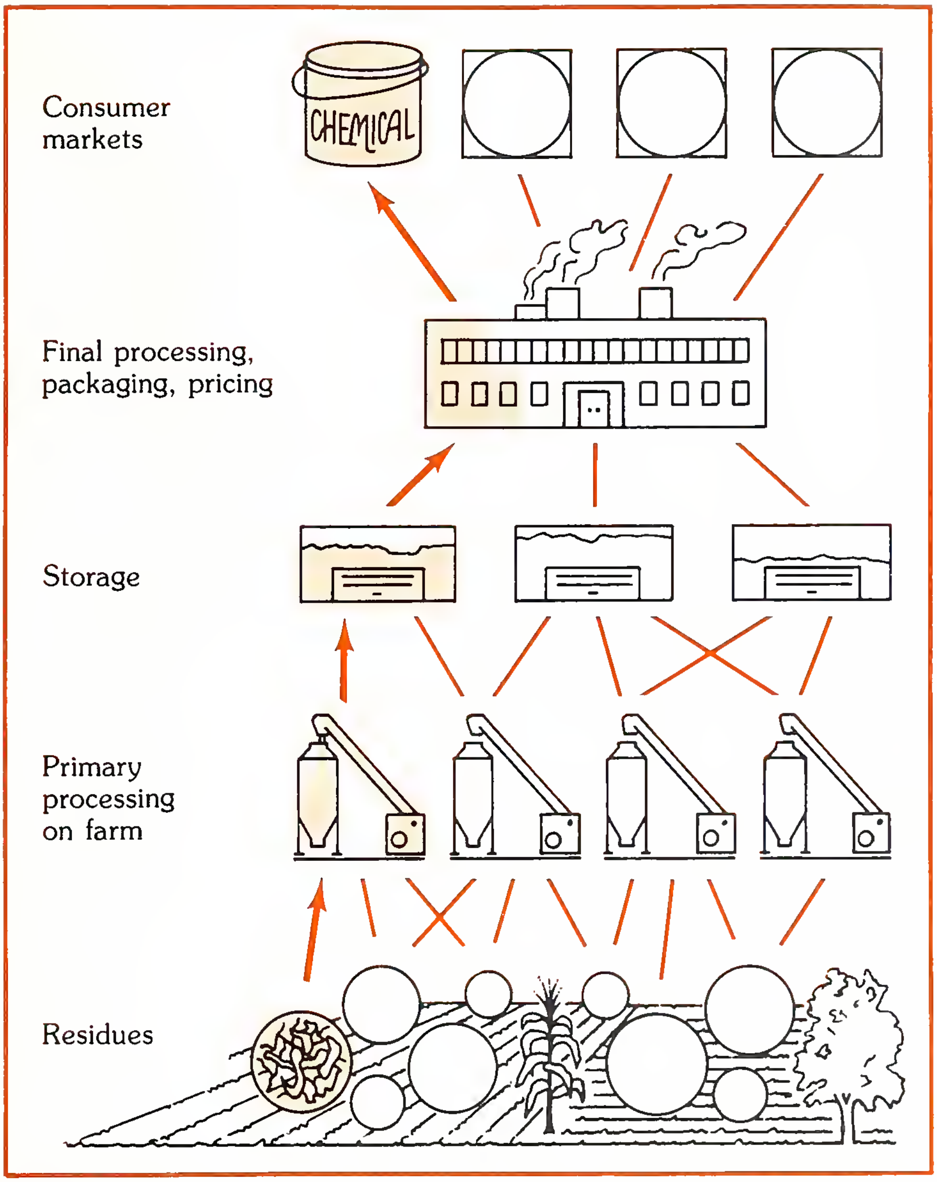


Fig. 1. Agricultural supply system. Farm products undergo many stages of processing and storage between production and consumer markets. Transportation is the indispensable link uniting points in the system.

Fig. 2. A baling machine gathers crop residues into large round bales. Indoor storage facilities are unnecessary because the bales are rain-resistant.

numerical values of the constants, variables, process output-input ratios, and other technical coefficients.

Raw material supply system. To successfully model the system, we must understand its characteristics. First, the most significant of them is that the materials are widely dispersed and thinly scattered over the fields (Fig. 1). Transporting residues to a central processing site is therefore expensive, although once there, economies of scale are expected.

Second, the materials are bulky and at current prices don't have much value. Either they have to be transported cheaply or their density has to be increased at little cost if the farmer is to have an economic incentive for marketing them.

Third, raw materials are often both difficult and expensive to reclaim because discarded residues tend to be contaminated with soil and to have a high moisture content. Consequently, they are not entirely suitable for further processing and may have a short storage life.

Fourth, the quantities of crop residues available will depend on the amount needed to retard soil erosion on unprotected row crop acreage. Any proposed supply system must consider this potential constraint.

A fifth characteristic is that the energy content of some raw materials is very low. More energy is therefore spent for conversion than is available from the end product. And finally, consumers may discriminate against a new system that changes an established, convenient one. For example, they may object strenuously if required to burn plant residues instead of natural gas for heat.

Not all of these constraints are rigid, however. Bulk density can be increased to make transportation more efficient. Rather than being dropped back into the soil, crop residues can be accumulated when the plant's fruit parts are harvested. Besides using scattered crop residues, farmers have other ways to reduce soil erosion. And consumer preferences do change under economic imperatives.

Fig. 3. Corn stalks are reclaimed with a flail forage harvester.

Feasible systems. No system that supplies raw materials from plants has yet been widely accepted, but interest has developed in the past few years. Several subsystems with special machine requirements have already been evaluated. For example, the large round baler has been used successfully to gather residues (Fig. 2). With this method, the round bales can be stored outdoors because they tend to shed rain.

The residue from corn, the nation's most widely grown crop, is a likely choice for retrieval subsystems. Compared with soybeans and small grain crops, corn produces substantially more residue. In the Midwest it amounts to about 3 tons per acre (6.7 metric tons/ha), 15 percent of which is corn cobs.

A flail forage harvester (Fig. 3) gathers corn residue after conventional combine harvest. Capable of picking up only about half the residue, the harvester leaves the remainder for soil conservation. Unfortu-

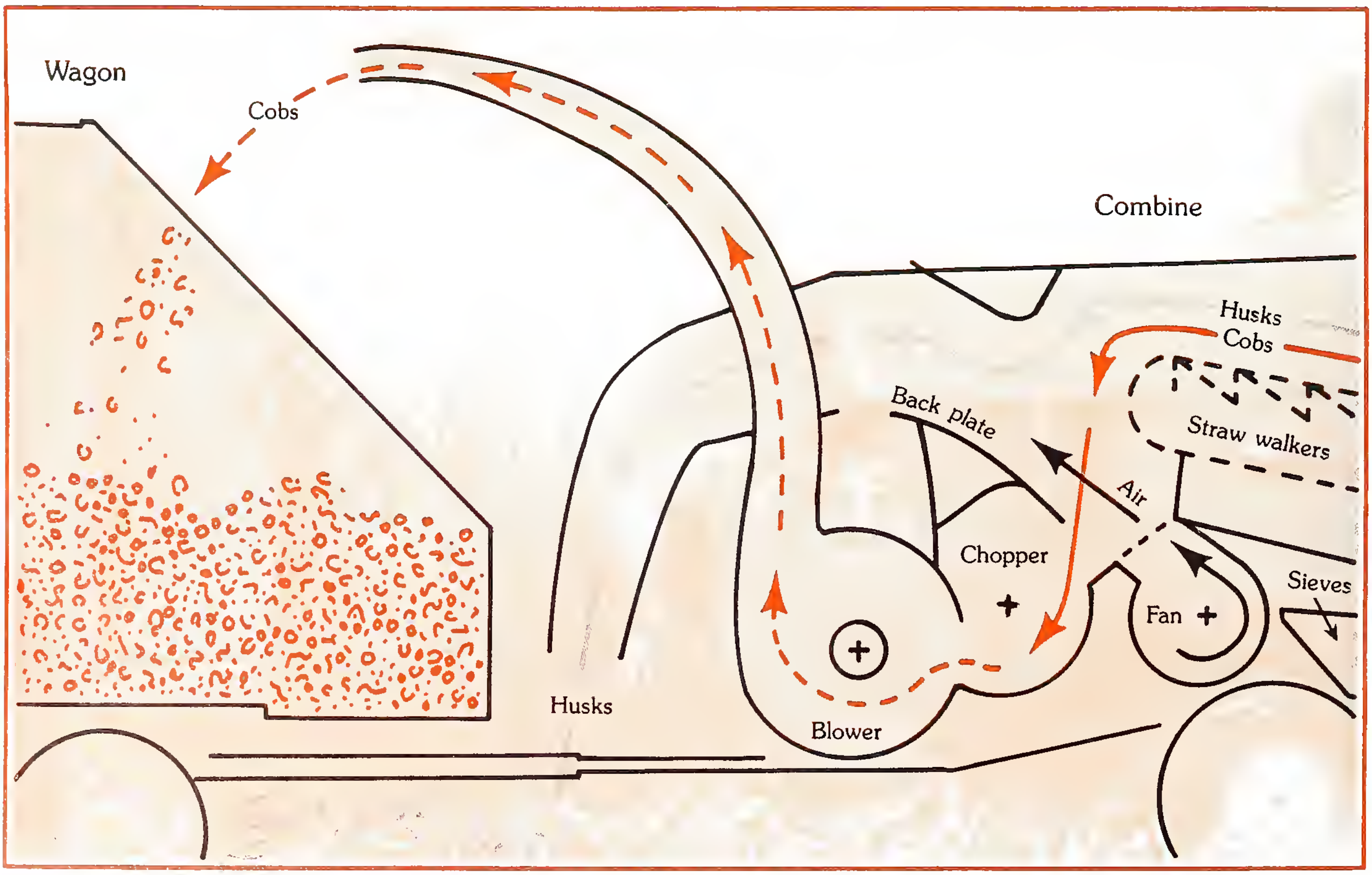


Fig. 4. Diagram of a mechanism for salvaging corn cobs. Attached to the back of a combine, the mechanism chops the cobs and shoots them into a trailing wagon.

nately, the reclaimed material usually has a high moisture content and is contaminated with soil. Furthermore, the mechanism leaves behind many of the corn cobs, which do little for soil conservation but may be the most acceptable raw material for industry.

To circumvent this problem, agricultural engineers at Purdue University have developed a cob-saving mechanism for the discharge end of a combine (Fig. 4). Because of their higher density, the cobs are delivered to a trailing wagon, while the husks are blown out. The cobs (and some husks) are chopped to a homogeneous mass that can be handled by blowers and grain elevators.

Industry has a history of using cobs as a raw material. When it was customary to harvest ear corn, the cobs produced at corn-shelling sites were sold at a profit. But transporting them by truck was not very efficient because of the low density of the cob load. A systems analysis may indicate that a baler or compressor to increase cob density would improve the economies of using cobs as a raw material.

The agricultural community should not overlook other feasible systems that include the use of crops specifically grown for industrial use. Among the possibilities are sweet sorghum and Jerusalem artichokes for sugar, kenaf and cottonwood for cellulose, and castor beans and safflower for oil. A thorough systems analysis will also evaluate other crops.

Forecast. At present, agriculture is unable to meet the nation's demand for hydrocarbon materials. Even if all crop residues were used, they would comprise only about 5 percent of our total energy needs. Future energy requirements will have to be met by coal and then nuclear power. Solar collectors that shade the soil will have to compete economically for land used to produce our grass, forest, and grain crops. The development of an agricultural raw material supply system will be a truly formidable task.

Donnell R. Hunt, professor of agricultural engineering

How Markets Develop: Two Case Histories

Susan E. Offutt and Robert J. Hauser

In the best of all possible worlds, when technological advances open the door to unconventional uses of agricultural raw materials, end products and the new markets for them emerge simultaneously. In reality, however, such symbiosis seldom exists and may be slow to develop. By reviewing the past and considering the future of unconventional products derived from corn, we can perhaps identify those conditions that promote the economic success of a new product.

Current and future uses of corn. Traditionally, most U.S. corn has been earmarked for livestock feed, both domestic and exported. Roughly 85 percent of the corn used annually in the United States goes to the beef, pork, and poultry sectors. Of the remainder, less than 0.5 percent is reserved for seed, 13 percent for food and industrial uses, and 2 percent for alcoholic beverages.

In absolute terms, the seed corn and alcoholic beverage components have grown little over the past thirty years. Together they account for about 90 million bushels (2.3 million metric tons, MMT) annually. In contrast, food and industrial uses have more than tripled, funneling off some 775 million bushels (19.7 MMT) in 1982-83. Corn for feed still dominates, however. In 1982-83 about 4.5 billion bushels (114 MMT) were consumed domestically and another 2 billion bushels (50 MMT) were exported.

In the future, the conventional feed market for corn will remain dominant, although total demand will vary somewhat with livestock production cycles. No dramatic expansion in the use of corn for alcoholic beverages is likely. The most dynamic sector of the market will continue to be the one that channels corn into food and especially industrial uses.

Unconventional uses of corn by industry will probably require wet milling, a process that separates the kernel into germ, hull, gluten, and starch. Over the past decade, large quantities of starch converted into high fructose corn syrup (HFCS) have been substituted for sugar as a sweetener, most notably in soft drinks. The use of starch fermented into ethanol for a stand-alone fuel or an octane-enhancer also increased markedly.

Increases in industrial corn use will probably arise through the conversion of starch into intermediate chemicals that can replace those now derived from petroleum. Clues about marketing these new products can be gathered by examining how the markets for HFCS and ethanol have developed.

HFCS and ethanol markets. U.S. per capita consumption of corn sweetener has grown from its 1972 level of 21 pounds per year to 45 pounds (10 and 20 kg). Increased use of HFCS, with consumption of sucrose and dextrose holding steady, accounts for much of this growth. In 1972 the average American consumed about one pound of HFCS, compared with an estimated 25 pounds (0.45 and 11 kg) in 1984. More than 350 million bushels of corn (8.9 MMT) will be needed to meet this demand.

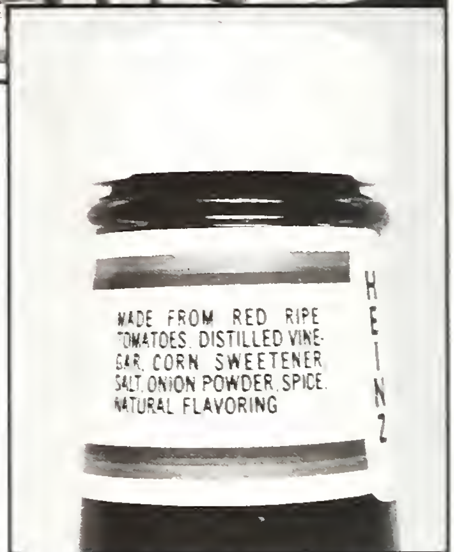
In the case of ethanol, the fermentation process is of course nothing new, but large-scale production is quite recent. Large production plants started coming on line in 1979. Although their capacity for corn use is

not well documented, they could probably handle between 125 and 150 million bushels (3.2 and 3.8 MMT) per year. Current production taps only one-half to two-thirds of this capacity.

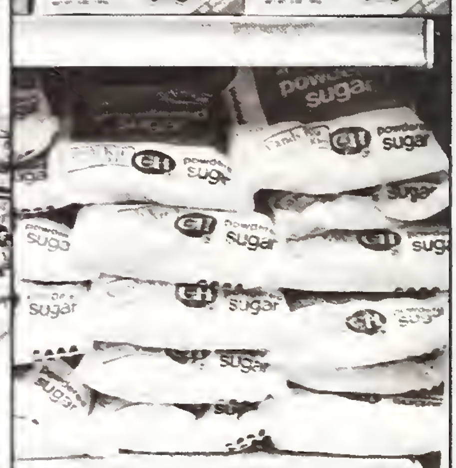
The HFCS and ethanol markets, which were virtually nonexistent in 1970, now account for nearly half of the nonfeed domestic utilization of corn. Roughly a third of the processing occurs in Illinois. According to recent estimates, these two markets will cause a long-term price increase of 13 to 20 cents per bushel ($5 to $8 per MMT). (The estimates do not account for increases in government price supports.) Furthermore, these markets could ultimately create more than $500 million of increased economic activity in Illinois through direct and indirect income generation.

Although both markets have grown tremendously, they evolved in different ways. In the mid-1970s, when prices for cane and beet sugar were high, the HFCS market developed as technological advances brought down the cost of production. Most of the sweetener was used in carbonated beverages and ketchup. Sugar prices subsequently fell, however, and large potential users of HFCS have hesitated to switch to the corn sweetener. Their reluctance arises from uncertainty over the direction of agricultural support programs, both foreign and domestic, which could keep cane and beet sugar prices relatively low and stable.

Ethanol production got its impetus for rapid expansion largely from federal and state legislation during the energy crisis of the mid-1970s. Many plant starts and expansions were encouraged by federal and state subsidies in the form of exemptions from excise and sales taxes, investment tax credits, research and development programs, grants, subsidized loans, and loan guarantees. Even though many of these programs are being phased out, large plants have become efficient enough that they are now able to offer ethanol to petroleum refiners as an octane-enhancer.



High fructose corn syrup (HFCS) has replaced cane and beet sugar in some brands of soft drinks and ketchup. Other forms of natural corn sweetner can be purchased in supermarkets for table use.



Market expansion. The economic success of unconventional products depends in varying degrees on supply requirements and the characteristics of end-use markets. New products that require changes in cultivation, harvesting, or storage practices may have to be developed slowly. Large capital investment in existing machinery tends to discourage its rapid turnover. For example, farmers across the Corn Belt switched to combines with corn heads to replace mechanical pickers. They are therefore likely to resist the introduction of new products that require more or altogether different machinery to recover other parts of the corn plant. Similarly, product development will be slow if it depends on new varieties with characteristics very different from the hybrids now in common use.

This bias towards traditional grain production is also reflected in the transportation system, which is designed to expedite the handling of grain for domestic feed and for export. Expansion of the HFCS and ethanol markets has been rapid, in part because current production and transportation practices did not need to be modified for the new markets.

Even if existing supply and processing technologies are adaptable to the new use, economic success in the market depends upon price relationships. For instance, is the new product intended as a substitute for existing products? Is the market for those products expanding? Or would the product define a new market altogether? Both HFCS and ethanol are substitutes for other products. In each case, the escalating prices of sugar and petroleum were important, but so were the effects of government policies on commodity markets.

Markets for these unconventional corn products were subsequently expanded, primarily at the expense of the existing products. Ethanol and HFCS will continue to grow if relative prices are favorable and if the end-use markets can absorb increased amounts. However, recent consumer resistance to ethanol fuels may put a brake on growth, even if demand for unleaded fuels continues to expand. On the other hand, public concern about the effects that new artificial sweeteners may have on health could help keep the market for natural sweeteners vigorous.

The outlook for new uses of corn and other agricultural raw materials will depend on changes in market conditions for substitutes and on anticipated growth in new or existing markets. In the United States, new food products will probably show little growth, except perhaps as so-called health foods replace more highly processed foods. Demand for food is generally unresponsive to changes in prices or income. Consequently, the derived demand for the required agricultural raw materials will not grow tremendously. The outlook is brighter for industrial chemicals and other nonfood products. Conversion of corn stalks and other cellulosic materials to ethanol and furfural shows some promise.

Effects of government policies. The pervasive influence of government policies on market price relationships is of paramount importance. In the case of ethanol, fuel subsidies continue to be significant in bolstering the product's economic success. In addition, the economic appeal of ethanol plants depends to some extent on the credit received for corn gluten feed, which remains as a by-product when corn is separated into oil and fermentable starch.

At present, large quantities of this by-product are exported to the European Community. The Community, however, has considered restricting imports of the feed, an action that could drive the U.S. price down and thereby diminish the by-product credit.

In the sweetener market, government policies restrict imports of foreign cane and beet sugar and maintain domestic prices above world levels, thus enhancing the appeal of lower-cost HFCS. Any shift towards a less protectionist stance could jeopardize the cost advantage enjoyed by the corn sweetener.

The current farm bill will expire in 1985, and agricultural policies may undergo substantial revision. Moves to restrict production and thereby increase returns to growers through higher prices would probably discourage the expansion of markets for some unconventional products. On the other hand, policies that give market forces more rein, tending towards continued high production levels, would probably exert less upward pressure on commodity prices and provide a better environment to develop new product markets.

In any event, relative prices in both raw material and end-use markets will continue to feel the influence of government actions. The effects of these actions must not be ignored in assessing the prospects for success of new products from agricultural materials.

Susan E. Offutt and Robert J. Hauser, assistant professors of agricultural economics

In Progress

Malaria and monkeys

Worldwide, malaria is considered the Number 1 infectious disease of humans. Each year it affects some 200 million people, killing between 3 and 5 million. The disease is a public health problem of international proportions with severe economic implications. An urgently needed vaccine against malaria is now being developed by a University of Illinois research team. Veterinary pathobiologists Miodrag Ristic and Mark James are the team leaders.

Caused by a blood protozoan parasite, malaria is transmitted to humans by mosquitoes. The scientists are working with the erythrocytic stages of the pathogenic malaria parasite *Plasmodium falciparum*.

They found that, when the parasite is grown in cell cultures, large quantities of soluble protein antigens are naturally released into the culture medium. (An antigen is a foreign substance, such as a bacterium or cancer cell, that is capable of stimulating an immune response.) At present these antigens are being purified for biochemical analyses that will pave the way for large-scale vaccine production by recombinant DNA technology.

To aid their studies, the researchers are using South American squirrel monkeys as a primate experimental model for vaccination trials. Purified antigens are being tested for their ability to protect the monkeys against disease caused by infection with virulent malarial organisms.

South American squirrel monkeys used in research to find a malaria vaccine.

Biotechnology Center

Cooperation is the watchword of members belonging to the new Biotechnology Center and Affiliates Program, which was inaugurated May 30 and 31 on the Urbana-Champaign campus. Representatives of nearly fifty industries nationwide and from England and France attended the opening. During the two days of activities, scientists from campus presented talks on basic and applied biological research, genetic engineering, and its agricultural and medical applications.

As participants of this cooperative endeavor between industry and the University of Illinois, affiliates will be entitled to consult with scientists engaged in basic research related to biotechnology. Participants will also have the opportunity to attend an annual workshop and will receive notice of seminars and the publications generated by research activities. Current listings of faculty and postdoctoral associates and their projects will be available as well. Annual fees for participation in the Affiliates Program are based upon a company's size, as measured by gross sales.

The Biotechnology Center is the brainchild of several scientists who recognized the strength of research programs already existing in many academic departments throughout the campus. Theodore Brown, vice-chancellor for research, guided the center's organization, and Samuel Kaplan, professor of microbiology, is its head.

Rabbits and reproduction

The domestic rabbit is an efficient producer of lean meat. Now that researchers have begun to appreciate this fact, they are studying the physiology of the rabbit to find ways of improving its reproduction. Janice Bahr, professor of animal science, and research assistant Romana Nowak are concentrating on two main areas.

First, they are looking at the effects of season on reproductive efficiency in the doe. The doe is definitely more sexually receptive in the springtime than during other seasons, Bahr says. Peak receptivity occurs as daylength increases, usually from February to July.

Changes in receptivity are correlated with certain reproductive hormones. Bahr and Nowak have found that lutenizing hormone and prolactin vary with the season. Both hormones reach their highest levels in the spring and their lowest levels in the fall as daylength decreases.

The second major area of research is centered on maternal recognition of pregnancy. Exactly how the fetus signals its presence to the ovary of the mother needs to be determined. Whatever the signal, it allows the corpus luteum to continue secreting the hormone progesterone throughout pregnancy. The researchers have determined that progesterone production from day 12 of pregnancy on requires the presence of the fetus and placenta.

Bahr and Nowak are now focusing on the types of factors produced by the placenta and whether they serve as the signal for pregnancy. Recent work in their lab has shown that the rabbit placenta contains gonadotropin-releasing hormone. The significance of a placental source of the hormone and its role during pregnancy will be investigated.

Potato-soyburger

Ground soybeans and potatoes prepared as high protein patties.

A new taste treat may be in store for potato lovers the world over. Potato-soy patties, developed by L. S. Wei and colleagues in the Department of Food Science, have so far received high marks for flavor, appearance, and texture. Widespread acceptance is the next big test the combination food will have to pass.

The patties were not intended simply to wake up tired taste buds. Rather, they were developed as a means of introducing soybeans into the diets of people who cannot afford to buy meat. When added to potatoes, ground soybeans triple the amount of protein contained in potato patties alone.

So far several recipes have been concocted to fit into the traditional dietary pattern of Sri Lanka. For example, a bit of finely chopped onion and green pepper can be added to the potato-soybean mixture. Rolled in bread crumbs and fried to a golden brown, the cutlet has proved both nutritious and delicious. Other variations call for curry powder and a pinch of turmeric. Imagination can spice the basic mixture to suit the individual palate.

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Illinois Research

Fall 1984

Families:
their values
and problems

Illinois Research

Agricultural Experiment Station
Fall 1984

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 26, Number 4

The Cover

The structure of the American family is changing drastically. Many marriages now end in divorce, and a significant number of children are being raised by only one parent, usually the mother. Even so-called traditional families may feel repercussions from the changes around them. Researchers in many disciplines are pooling their efforts to study these changes. Their goal is to find ways of helping families of all types solve their problems.

"At a time unlike any in the past, we must envision the future."

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Contents

Family-Centered Research

Despite drastic changes in its structure, the family remains the basic unit of our society. Today, however, the traditional family is less common than it once was. In fact, it is projected that nearly half of the children in the United States will live for at least several years in single-parent households headed primarily by women. Focusing on families of all types, the field of home economics studies the way families manage their resources, clarify values, and achieve satisfying personal relationships.

Of great concern to home economics professionals are the effects of change on family members, particularly on women and children. This issue of *Illinois Research* provides information about the integrative research efforts of faculty members in the School of Human Resources and Family Studies, a component of the College of Agriculture. Many of the School's research projects are supported by the Agricultural Experiment Station.

One article addresses the need for women to be financially competent, given the increasing number of female-headed families and the fact that women frequently outlive their spouses. Another report looks at whether cost or convenience is given higher priority in the purchase of food, clothing, and household equipment. The author compares the buying patterns of single parents, two-earner families, and traditional families in which the mother is a full-time homemaker.

Yet another article examines societal influences on the decision to marry; the characteristics of premarital relationships may eventually be used to predict marital success. Also included in this issue is a discussion of family violence and some proposed remedies. In the last report, the authors compare the educational attainments of young men and women from one-parent and two-parent families.

Changes in family structure have created a need for social programs to help families under stress. When income is low, for example, female heads of households may benefit from programs to improve job skills and to develop strategies for managing financial and other resources. In future years, home economists will continue to study ways of helping families solve their problems. Although the problems may be quite different from those encountered by pioneers in the field, the need for solutions is no less real.

Marjorie E. Mead, professor and head, Department of Textiles, Apparel, and Interior Design

The Changing Family

Problems, Strengths, and Values of Today's Families

Hazel Taylor Spitze

What is a family? For some people this word calls to mind the traditional image of an employed father, stay-at-home mother, two children, and a dog behind the picket fence. Others picture an employed single parent (usually the mother) with small children; a young, dual-career couple with or without children; or an elderly couple whose children have grown up and moved away.

The American Home Economics Association defines the family even more broadly as "a unit of intimate, transacting and interdependent persons who share some values and goals, responsibility for decisions and resources, and have commitment to one another over time." But regardless of the picture, most researchers agree that the family is still the basic unit of our society and is likely to remain so. It is this unit that the profession of home economics takes as its focal point and field of study.

Family problems. Families of every description face similar problems such as managing their financial resources and using their time. Problems in communication and human relationships may result in the abuse, or even death, of children, spouses, the elderly, and the handicapped. Often families encounter problems in providing for the needs, including the education, of individual members.

Families may have problems clarifying their value systems and understanding differences in values among family members and across generations. The use of time, talents, and community resources, as well as the allocation of a family's resources among its members, may pose problems. Similarly, difficulties may arise when a family interacts with other families and societal institutions — from businesses to service organizations, from schools to law enforcement agencies, and from churches to health care providers.

Opportunities and strengths. Alongside these problems, however, exist strengths and opportunities that become manifest by the way that problems are met. For example, families have the opportunity to nurture their members physically and to build self-esteem. They can provide education for their members and help develop attitudes that make them employable. Family members can inspire one another, help develop skills and talents, offer security, present challenges, and reward effort.

Among a family's strengths are the ability to care, their contributions to other families and institutions, and the time and skills used to improve the quality of life for their own members and for society. There is also strength in their positive feelings and expectations for each other and in the physical and mental health of some or all of the members.

Values. Beliefs held strongly enough to influence action constitute a family's values. They can spur individuals to expend great energy in caring for one another, in taking unusual care of their own health, or in serving others. Positive values can set high educational or career aspirations and encourage the development of special skills and talents.

Unfortunately, family values may also have negative effects. If family members value great wealth regardless of how it is acquired or freedom without responsibility, then problems are created that may require the in-

A portrait of today's family is easily distinguished from the family portraits of a generation ago. Now there tend to be fewer children, the mother often has a career other than homemaking, and the father shoulders his share of household tasks. In fact, a family is any "unit of intimate, transacting and interdependent persons who share some values and goals, responsibility for decisions and resources, and have commitment to one another over time," according to the American Home Economics Association.

tervention of social service agencies. Likewise, opportunities and strengths can be undermined if families devalue work and become dependent on society, or if authoritarian parents believe that physical or emotional abuse is necessary to control their children.

Integrated studies of the family. The problems that beset today's families don't fit neatly into a single area of study. Hence, researchers from different disciplines often work as a team. Even those working alone usually look at a problem from several different perspectives. Thus we have integrated approaches to problem-solving. For example, scientists in foods and nutrition may study the effects of dietary intake on the human body, while researchers in health education may look at the effects of health on the ability to work, on the development of self-confidence, or on one's relationships with others.

Some researchers may study how clothing and housing affect self-esteem or employability, while those in family and consumer economics may investigate family decisions on the use of resources or the effect of values on nonmarket production. Specialists in human development and relationships may study the way employment affects family life and vice versa or the extent to which values influence the educational aspirations and attainment of family members.

Few problems stand in isolation. When experts from many backgrounds work together, problems that tend to be interrelated are more likely to be solved than when each problem is viewed from a narrow perspective. This orientation is greatly needed among psychologists, economists, anthropologists, artists, physiologists, and other specialists who are employed in academic units related to family studies and home economics. Families and the society in general are likely to benefit from the integration of research on various aspects of family life.

The profession of home economics, focusing as it does on families, brings many disciplines together. Members of the profession serve families, using the results of their research to help both traditional and nontraditional families prevent crises, reduce their need for support from service agencies, and grow in their ability to function successfully.

Hazel Taylor Spitze, professor of home economics education, College of Education

Financial Education of Children

Kathryn D. Rettig

Managing financial resources in the family is always a challenge. In recent years, though, it has become even more demanding because of changes in the economic climate and the banking deregulation process. The shift from inflationary prosperity to recession requires frequent adjustments in savings-investment strategies. Faced with many new savings instruments, the family manager must learn about a confusing array of financial supermarkets.

It is important to the economic well-being of the family that its manager possess adequate information and the experience necessary to make effective decisions. What are families doing to prepare their younger members to assume this exacting managerial role?

Consumer education in the home. A recent study initiated in the School of Human Resources and Family Studies sought information about the ways families transfer information, values, and financial management know-how from one generation to the next. Often labeled "consumer socialization," this area of research focuses on the processes by which young people acquire the skills, knowledge, and attitudes that will help them as consumers in the marketplace and as financial managers in the home.

In the past, market researchers have not taken much interest in the consumer behavior of young children, nor have socialization researchers concentrated on consumer or financial learning behaviors. Those studies that do exist suggest that this kind of learning in families is more subtle than purposive or systematic. According to one study, parents have few specific consumer goals for their children and rarely give them direct training in financial matters.

When training does occur, older rather than younger children are singled out. Most children probably learn these skills primarily through imitation and observation. However, theories of observational and imitational learning have not been applied explicitly to consumer socialization research.

Male versus female training. Earlier studies suggest a difference in the home-based financial education of male and female children. Studies in 1897, 1934, and 1945 focused on family practices in preparing children to manage money. Compared with girls, the boys were better trained in the use of money because they were given more opportunities to earn money and to learn its use in the marketplace. We would like to think that parents today are more enlightened than their predecessors about these gender-based practices, but in fact we know very little about the financial education occurring in families.

Consumer education programs. Illinois requires all high school students to take a course in consumer education. The Cooperative Extension Service also has financial education programming. For this type of education to be effective, information is needed about financial management behaviors of families.

Several questions need to be asked. What kinds of consumer be-

Author Kathryn Rettig has made a point of educating her own daughters in family and consumer finances. Training can begin with giving young children an allowance and teaching them how to use a simple budget. Later on they can be introduced to financial planning, record keeping, insurance policy coverages, and the contents of the parent's will.

haviors are transmitted across generations? Which behaviors are modified as a result of social trends or peer influences? How do early learning experiences influence adult patterns? Are male and female children given equal opportunities in the family to acquire financial management information and skills?

The study. To answer these questions, we randomly selected a sample of 609 mothers with at least one child under 19 years of age from households in Illinois. In telephone interviews, the women were asked about certain attitudes, values, and feelings related to family life. We also questioned the respondents about the financial experiences that their own parents provided and that they will probably transfer to their oldest child.

Nine types of experiences or information were included in the questionnaire:

- receiving an allowance
- using a budget
- assisting with record keeping
- participating in discussions about major financial decisions
- knowing the amount of family income
- understanding auto insurance coverages
- knowing about life insurance protection
- location of important financial documents
- being familiar with the contents of the parents' will

Results of the survey, and also of a pretest of the survey questionnaire, seem to indicate that female children in Illinois families receive little information or experience in these nine areas. In the pretest during May 1983, many of the 161 participating female students at one of the Illinois state colleges indicated that they had not received fundamental financial information from their parents. Most (71 percent) were not taught to use a written budget and 62 percent were never included in planning the use of family income.

Record keeping and filing were also not part of the students' experi-

All About Us contains forms and suggestions for keeping family records. The pages are packaged in a handy-to-use loose-leaf binder. Important information about insurance policies, financial assets, and the like can be kept under one cover. Sections are also provided for recording the location of documents such as wills and birth certificates. Parents can use *All About Us* as an aid in teaching their children how to become intelligent consumers and competent family managers. The book costs $12 and can be ordered through the Office of Agricultural Publications, University of Illinois at Urbana-Champaign, 47 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801.

ence; 83 percent had not helped keep records of family expenses and 71 percent had not been shown how to use the family filing system. In case of a serious family crisis such as the death of the parents, 50 percent would not have known where to find necessary documents.

Most of the students (74 percent) did not know the contents of their parents' will, and 61 percent were unfamiliar with the life insurance policies or coverages. In families where the daughter knew about the automobile insurance policy, only 47 percent were familiar with its liability coverage.

Older than the college students in the pretest, respondents in the survey itself averaged 36 years of age. Other characteristics of the sample are as follows:

Marital status	***Percent***
First marriage, averaging 10 years	74
Second marriage	9
Separated, divorced, widowed	12
Never married	5
Employment status	
Unemployed outside the home	42
Employed full-time	36
Employed part-time	22
Education	
Less than high school	9
High school graduate	45
Some college	27
College graduate	12
Some graduate work	7

It is interesting to note that 14 percent of the adult respondents had not been exposed by their family of orientation to any of the nine kinds of financial experience mentioned above. Those who had received any of this information usually reported only three yes answers for the questions in the set.

Like the college students in the pretest sample, many of the adult respondents (59 percent) had not been taught by their parents to use a written budget. However, only 25 percent of these mothers admitted not having taught their oldest child this financial planning skill. Although 77 percent of the respondents had not been included in discussions of financial decisions in their family of orientation, 45 percent said they did include their oldest child in such discussions. The most appropriate age for children to be included, they thought, was between 10 and 12 years.

Financial record keeping was also ignored in the early education of these mothers; only 9 percent of them had had that experience in the family setting. The pattern tended to repeat itself, since only 15 percent of the mothers provided this opportunity for their oldest child. It should be pointed out that assistance with record keeping is a subtle but effective way to help children appreciate the total demands on family income and how their own needs must fit within the limits of the budget.

Respondents typically did not learn of life insurance coverage (67 percent), auto insurance coverages (67 percent), the location of important documents (47 percent), or the contents of their parents' will (64 percent). Those who did receive this information from their parents were informed when they were between 16 and 30 years of age.

One difficulty in assessing change in family educational practices in the second generation is the fact that 38 percent of the mothers had very young children and thus had not yet had the opportunity to do much financial education. However, the remaining 62 percent who did have the opportunity reported some changes. If these mothers are actually educating their own children as they reported, then some positive results are occurring in the transfer of financial information in the family. Only 35 percent of this group had not explained the life insurance and 27 percent the auto insurance policies. These mothers expect to do so when the child is 16 years old. Similarly, 27 percent had not discussed the location of important documents and the contents of the will with the oldest child.

In future analyses it will be important to compare the mothers' financial education practices with their years of education, marital histories, and family life styles. Mothers who place a high value on independence and self-reliance are expected to transfer considerable information to children, particularly girls, when they are relatively young. Parents who communicate financial information openly are expected to be fairly satisfied with the communication and quality of life in their family.

Women and financial skills. Given the increasing number of female-headed, single-parent families with low incomes, there is a critical need for women to gain skills in financial mangement. Even when employed, women are often in occupations with no pension plans or are disqualified because of discontinuous employment. Despite being married, women may not have pension benefits if the spouse has not elected joint and survivor benefits; if he is not vested; if he dies before reaching retirement age; or if the husband and wife divorce. (Vesting describes the conditions under which the money paid into a retirement fund by an employer legally becomes the employee's money.)

When one also considers that women have a longer life expectancy than men, financial planning is vital if they are to have an adequate income in later years. Families should therefore teach their female children how to be responsible for their own economic security, even though some of them will eventually marry.

It is hoped that the results of this study will prove helpful in the financial education of children in the family and in consumer education programs throughout Illinois. With this assistance, individuals and families should be able to improve communication about finances so that they can manage their resources as effectively as possible.

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Time Versus Money In Illinois Households

Michelle A. Morganosky

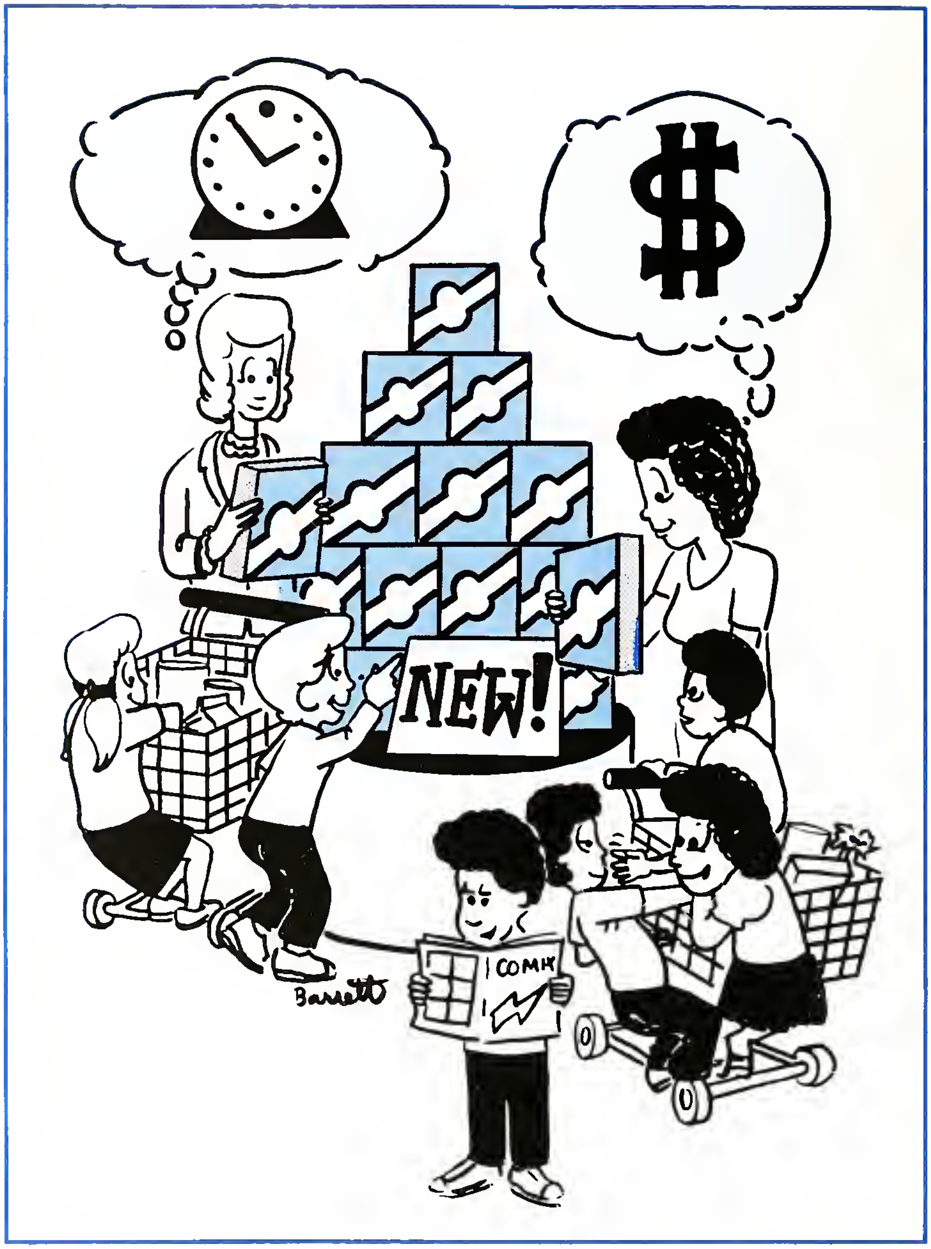
Time is money. Although this saying is often repeated, there is reason to question how consciously parents and product manufacturers apply it to the changing American family.

Today's family is characterized by an increasing number of mothers working outside the home, the rise in single-parent families, and a decline in the number of children. We need to find out the extent to which these changes affect the use of time and money and how they influence everyday decisions about food, clothing, and household equipment.

For example, are mothers who work outside the home more likely than full-time homemakers to buy convenience foods? Do single parents tend to consider cost or convenience first when shopping for their children's clothing? Are two-earner families willing to pay for convenience features in electrical appliances?

These are just a few of the many practical questions we attempted to answer in a recent study. The objective of the research was to determine which is stressed more, cost or convenience, when families purchase food, clothing, and household equipment. This study differs from earlier ones in that all three product categories were considered in the same study. We did so to give us a more integrated look than separate studies can provide into the way Illinois families make decisions.

The sample consisted of 609 families with at least one child under 19 years of age. Respondents were chosen randomly from households throughout Illinois. By means of a telephone interview with the mother in each household, we asked a series of questions to determine whether



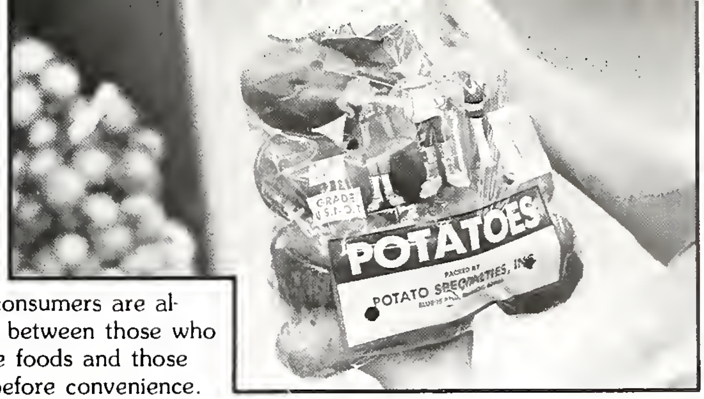
How much time will a new product save? How big a dent will it make in the family budget? Answers to these questions depend on family size, employment, marital status, and family income.

the families stressed cost or convenience when buying certain goods.

Overall, the repondents said that when purchasing clothing they tend to emphasize cost. The opposite was true for household equipment — more respondents were willing to pay extra for convenience features on refrigerators, ovens, and other appliances. In relation to food purchases, cost and convenience tended to be of roughly equal importance. Additional insights can be found by examining the data more closely.

Employment status of the mother. More than a third (36 percent) of the mothers in the study were employed full time outside the home. Twenty-two percent were employed part time, while 42 percent were full-time homemakers. How did employment status influence their purchasing decisions? Across all three product categories, full-time homemakers were more likely than employed homemakers to stress cost rather than convenience.

Interestingly, the women who



When buying food, consumers are almost equally divided between those who select easy-to-prepare foods and those who consider price before convenience.

worked part-time stressed convenience as often as those employed full-time. This finding suggests that both part-time and full-time jobs impose severe time constraints on working mothers. At the end of a workday, it takes far less of an employed homemaker's time and energy to bake a frozen pizza than to make one from scratch.

Family type. Single-parent families and two-earner families are becoming increasingly common. According to the data, about 14 percent of the women in the study were from single-parent families, 49 percent from two-earner families, and 37 percent from traditional families in which only the husband was employed.

For all three product categories, the two-earner families consistently opted for convenience features more often than did the single-parent or the traditional families. For single-parent families, on the other hand, cost was the overriding factor, probably because of monetary constraints.

Number and age of children. It is reasonable to assume that the more children in a household, the greater the demands on the mother's time. One would therefore expect mothers of relatively large families to stress time-saving features in products they buy. Contrary to expectations, the women with three to five children considered cost first, while those with one or two children emphasized convenience. This priority of cost over convenience in large families may be the reflection of a tight budget. A frost-free refrigerator eliminates the time-consuming chore of manually defrosting a refrigerator but costs more than a standard model.

By the same token, one might expect women with preschoolers to opt for convenience because of the many tasks entailed in caring for young children. We therefore compared the responses of mothers with children under 6 years of age with those having children 6 years and older. Generally, the mothers of young children were more concerned about cost than were mothers of children in the older age group.

Perhaps families with young children are still using a sizable part of their income to obtain, for example, housing with additional rooms. Established families with older children have often satisfied these needs. Another possible explanation for the emphasis on cost is that mothers of preschool children are less likely to be employed outside the home. Money is thus a greater constraint than time.

Income. To understand the extent to which income influences cost versus convenience, we compared the responses of families having an annual income of $20,000 or more with those having less than $20,000. Across all three product categories of food, clothing, and household equipment, the higher income families were apt to stress convenience while the lower income families stressed cost. In a sense, families can "buy" time as their income increases. For example, they can buy clothing at stores that are conveniently located even if the prices charged are higher than elsewhere.

Implications for producers. A profile of the typical convenience-oriented Illinois homemaker is that of a woman who is employed outside the home either full-time or part-time, who has one or two children above preschool age, who is a member of a two-earner family, and whose annual household income is $20,000 or more. Conversely, the typical cost-oriented homemaker tends not to be employed, has several young children, may be a single parent, and lives on less than $20,000 a year.

What message do these findings hold for producers of food, clothing, and household equipment? Given that families today — and probably in the future — have fewer children, more working mothers, and more single parents heading the household, product lines may need to be developed for both cost-oriented and convenience-oriented families. For example, single-parent families that are cost-conscious because of a relatively low income need products that suit their budget. Two-earner families in which the mother's time is at a premium may find that convenience in a product is paramount.

Producers of food, clothing, and household equipment have several options: they can emphasize either cost or convenience, or they can develop two product lines, one for families short on time and the other for families short on money. At present, producers seem to cater to the consumer's time constraints, as indicated by the many new products having convenience features that add to the cost of an item. The mixed preferences and needs of Illinois families surveyed in this study suggest that producers should also take cost into consideration.

Michelle A. Morganosky, assistant professor, Department of Textiles, Apparel, and Interior Design

Family Violence

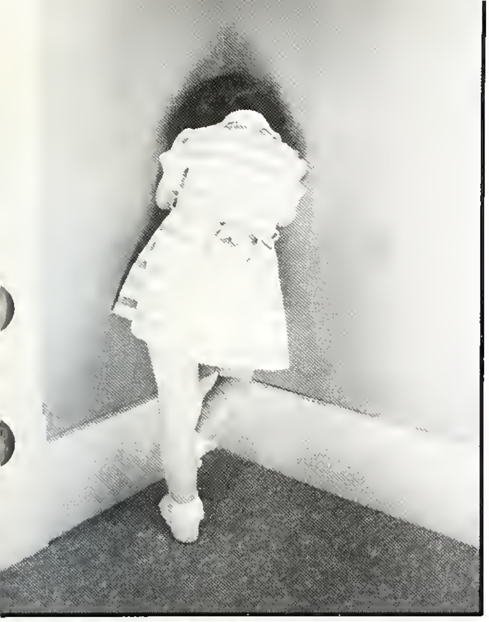
Rand D. Conger

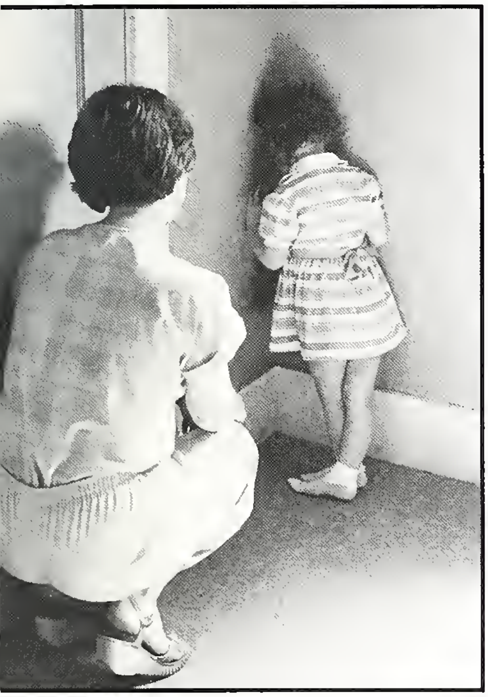
The American family is regarded as a haven of safety and warmth in a fast-paced society that tends to lose track of individual needs and concerns. In the ideal, family members rely on one another during times of crisis and celebrate joyful events together. Often enough, however, the ideal is never fully realized and may in fact be subverted by unresolved conflicts and even physical violence among family members. A recent study by a group of sociologists (Murray Straus, Richard Gelles, and Suzanne Steinmetz) suggests that abusive behavior within families is far more common than we like to think.

Incidence of abuse. Child abuse seldom occurs in public. It is therefore difficult to know the extent of the problem. From their study of more than 1,000 families throughout the United States, Straus and colleagues estimated that perhaps two million or more children are at risk each year for serious injury because of abusive behavior. This estimate does not include children who are sexually abused or those who are physically abused by people other than parents. If all instances of child maltreatment were combined, we would see a staggering total of epidemic proportions.

To make matters worse, parents tend to repeat abusive behavior. Thus a single report usually represents only a fraction of the child-directed violence that actually takes place. Besides the immediate physical pain and suffering, acts of violence and coercion by parents have been linked to social, emotional, legal, and academic problems for the developing child. For example, the

The firm but loving discipline enacted in this sequence of pictures suggests an effective alternative to physically abusive punishment. Here, the mother points out an inappropriate behavior — scattering clothes and bedding around the room — explains why the punishment is given, and then hugs her child in a gesture of reconciliation. Positive interactions at an early age help children learn how to treat family members.





New York State Assembly Select Committee on Child Abuse found when it reviewed the state's records that maltreated children are especially prone to delinquent or problem behavior later on.

The incidence of physical abuse between husbands and wives is no less common. From their national survey, Straus and colleagues concluded that almost two million wives and about two million husbands attack each other every year with enough violence to cause serious injury. Assaults on family members may very well be the most common type of violent crime in the United States today.

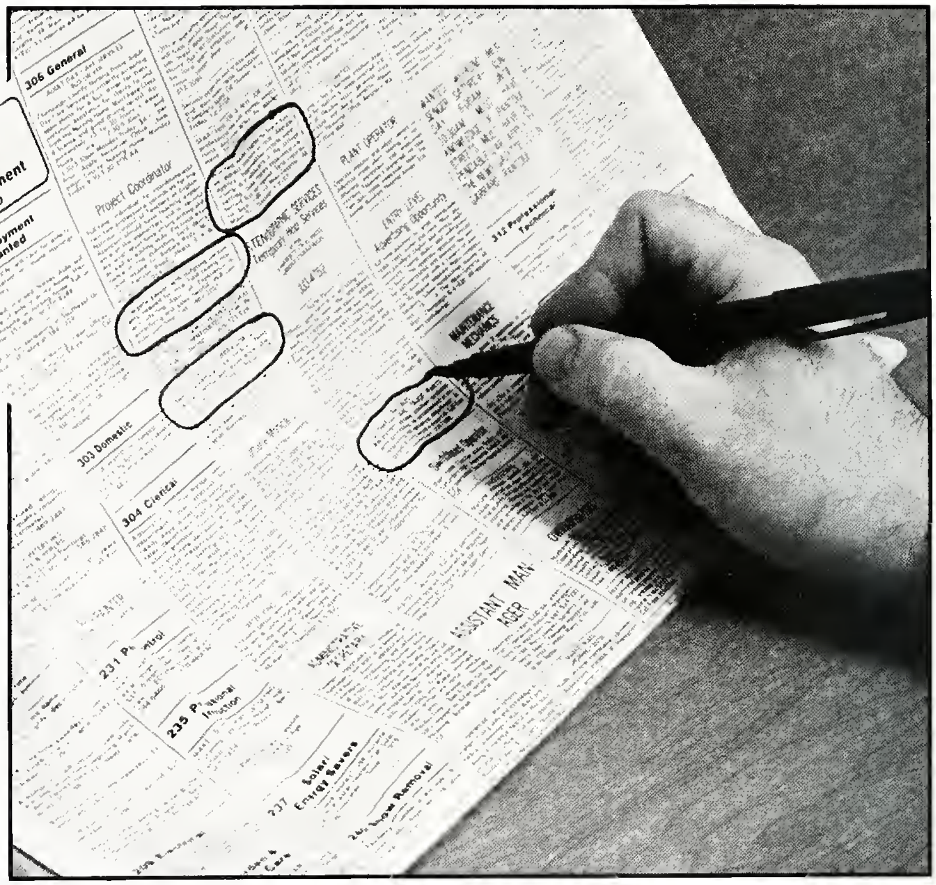
As with child abuse, violence between spouses usually continues over time. The severity of these conflicts is illustrated by the fact that domestic violence is one of the most dangerous and life-threatening situations that police officers encounter. Indeed, some investigators speak of violent families or violent homes, because entire families may be involved — spouses, children, and even siblings.

Some families appear to develop problem-solving styles that rely heavily on mutual control through punishment. Family members use physical coercion to settle decisions about the use of family funds and other important issues. At the very least, a violent home fails to provide the kind of emotional support that is linked to an individual's well-being. Physical violence can also lead to the emotional separation of family members, thus destroying the family's ability to provide comfort and stability for its members. Once a cycle of violence develops, the family unit itself may be torn apart if the parents divorce or children run away.

The roots of violence. Before attempting to decrease the incidence of family violence, we must first understand why it occurs. Results of numerous studies by investigators throughout the country suggest that the home environment may be one source of the problem. Just as children learn how to behave in school, with friends, and eventually on the job, they also learn how to treat family members. When parents physically abuse one another or their children, a youngster learns that physical force is one way to deal with the problems of everyday life. In fact, siblings who have physically abusive parents tend to be violent towards one another and eventually to mistreat their own spouses and offspring.

When coercive problem-solving techniques are learned early in life, a person may have difficulty developing more effective problem-solving skills later. Far from resolving family conflicts, the use of violence often breeds more violence. Youngsters raised in such an environment are poorly prepared to break the cycle. Over time, they may come to devalue family members and perhaps people in general. A lack of empathy for the feelings and needs of others can lead to additional abuse; and so the cycle goes on.

Quite apart from the home, many people from various walks of life believe that some form of physical punishment is acceptable. Several social surveys, including the one by Straus, have found that around 20 percent of the public even believes that hitting a spouse is appropriate on some occasions. Movies and television repeatedly dramatize problem solving through the use of force. The social consequences of this attitude are re-



The loss of a job or other stressful circumstances may trigger violence within a family. As a preventive measure, help in finding employment is one of many services that public agencies can offer to ease temporary stress.

flected in criminal statistics, which indicate that the United States has the highest rate of criminal violence in the western world. For many family members, then, the use of physical coercion to solve difficulties within the family can be learned from experiences outside the home.

People who are violent in the home are not necessarily abusive all the time, however. According to research recently completed at the University of Illinois, for example, it has been shown that abusive parental behavior can be triggered by stressful situations such as losing a job or having too many children for the available resources. In other research by James Garbarino, it was found that parents who rely on abusive punishment may lack the social skills necessary to stay on a friendly footing with others in the community.

Abusive parents tend to be socially isolated and to restrict the outside activities of their children as well. When in crisis or under stress, these families may receive little or no help from friends and neighbors. What goes on within a socially isolated family is kept private. Consequently, informal community ties cannot act as a check on excessive physical punishment in the home.

Remedies. Various steps can be taken to decrease family violence. But since the malady has many causes, the remedy requires different treatments. Preventive measures are high on the list. For example, we should implement social policies similar to those in Sweden and elsewhere to help reduce the amount of violence portrayed in the media. Movies and television play an important part in extolling the virtues of solving problems by force. Too often this message is aimed at family members who may translate fiction into reality.

After years of study, the Surgeon General has concluded that there is a link between television violence and individual behavior. Rather than dealing only with the physical and emotional aftermath of violence, an effective policy limiting media violence should help prevent the use of force among family members.

Two other areas involving social policy are crucial. First, because certain stressful circumstances can lead to family violence, public services should be provided to support families when stress is likely to increase. When a rise in unemployment is foreseen, for instance, a special effort should be made to alleviate the temporary stresses that families will face. Stress leading to conflict can also be chronic. To forestall one such situation — large family size — family planning should be readily available so that couples can contain the number of unexpected children who may become victims of environmental pressures.

Second, through public or private education every child should have the opportunity to learn effective alternatives to physical coercion. This opportunity is particularly vital for children who have seen violence in their own homes. Just as abusive behavior is learned, so too alternative behavior can be learned.

More than thirty years of developmental research has shown that children exposed to positive techniques of social interaction by nurturant caregivers have a better chance of developing normally. As adults, these children are more likely to establish stronger and more satisfying marital relationships, according to the Straus study. Family-life education in every school system is therefore an important social priority.

In addition to preventive measures, intervention programs should be available to serve families in which child or spouse abuse has been identified. The first step in any such program is to teach family members that conflicts can be successfully resolved through negotiation and understanding rather than by violence. In an ambitious program of research, psychologist David Wolfe demonstrated that abusive parents can improve their child-rearing skills and interact more effectively with their children without using physical punishment.

Many times, stress-relieving support services will be required to provide child care, emergency financial aid, or vocational training. Efforts should also be aimed at reducing social isolation by bringing a family into contact with community groups and activities. Programs for this purpose can be funded through state agencies such as the Department of Children and Family Services or they can be promoted through volunteer groups and religious organizations.

Of course, when violence in the family is extremely severe or chronic, the safety of individuals will sometimes require that spouses separate or that the children be placed in foster homes. Instead of falling back on solutions that ultimately destroy the family unit, however, we should put our energy into developing prevention programs that relieve stress and strengthen family ties.

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Tying the Knot: The Decision to Wed

Catherine A. Surra

When it comes to selecting the right marriage partner, people generally agree that courtship is an important testing ground for marriage. Many parents, other relatives, friends, and social scientists regard courtship as a time when partners actively test their compatibility and weigh the quality of their match.

Contrary to this popular view, recent research findings at the University of Illinois suggest that the decision to wed is less rational. Newlywed couples in the study were asked to reconstruct the events and the processes throughout courtship that prompted their commitment to wed. In response to the questions, they identified a wide range of reasons for the decision.

Many spouses, for instance, reported such predictable reasons as falling in love and enjoying each other's company. Some described marriages that happened almost by accident because of a big change such as the loss of a job or because marriage seemed the next logical step.

This article will discuss the results of research on why men and women choose their mates. Some attention will also be given to the value of this kind of research and to historical changes in the way people make the decision to marry.

Why study premarital relationships? The study is part of a series of investigations ultimately aimed at identifying those characteristics that predict marital success. Professionals and people in romantic relationships can use the information in a preventive way to help form sound relationships before the decision to wed is made.

Survey after survey indicates that close, satisfying relationships in general and a happy marriage in particular are among the most important contributors to personal well-being. Knowing what characteristics contribute to this sense of well-being is therefore critical to individuals in modern America.

The stakes in the dating game are high. If a person makes a poor choice, he or she will end up in an unhappy marriage. But because the emotional, social, and economic costs of divorce are prohibitive, some partners decide to stick with a marriage that is unsatisfying. These days, however, people are more likely to dissolve unhappy marriages. Demographic projections indicate that 40 percent of all first marriages between people who were 25 to 34 years of age in 1980 will end in divorce; some estimates range as high as 50 percent.

There are several reasons that individuals are more likely now than in the past to divorce. Among the social influences are the increasing economic independence of women and the declining stigma associated with being divorced. Changes in the meaning of a romantic relationship and other psychological factors also play a salient, but often underestimated, role in marital dissolution.

Historical changes in mate selection. In times past, people did not expect marriage to be their prime source of subjective well-being as we do today. Historically, marriages were often formed out of economic need and practical considerations such as the desire to have a helpmate. In recent times, the elusive experience of being in love — or believing oneself to be in love — has become the major criterion for deciding whom to marry.

The disparity between historical and contemporary views on love and marriage was aptly summed up by an elderly woman: "Well, I didn't marry the one I loved, but I loved the one I married." Rarely would anyone make a similar observation today.

The link between love and commitment is another change in our interpretation of romantic associations. It used to be that loving and remaining committed to a person were unrelated. In contemporary relationships, however, love and commitment usually rise and fall together. The close tie between the

two affects not only our decision to marry when we are in love, but also our inclination to end a marriage when love dies.

People now have more freedom of choice than ever before, with choices being based largely upon feelings. This new freedom is the essence of historical changes in mate selection. Feelings of closeness and intimacy serve as the background against which we select a spouse. In the foreground are a host of other conditions that influence these feelings.

The decision to wed. To map the process by which individuals choose the mates they do, newlywed couples were interviewed to learn how their courtships had evolved. Husbands and wives who had been married less than ten months were asked individually to provide graphs of changes in the likelihood that they would marry their partners from the time the relationships began until the wedding day (Fig. 1).

The respondents indicated each time they were aware of an upturn or a downturn in the chance of marriage. For every turning point in the graph, they were asked to provide details about why the change had occurred. The explanations were then classified into four categories: the intrapersonal, the relationship, the social network, and life circumstances.

Intrapersonal explanations usually have to do with what an individual believes about the institution of marriage, what a relationship leading to marriage is like, and what is expected of a marriage partner. For example, some people have internal clocks that say, "It's time for me to settle down." Graduating from high school or college and reaching a certain age are common alarms that sound and affect the decision to wed. Internal social clocks are powerful: being in a relationship at the "right" time is often more influential than the character of the relationship itself.

Many of the respondents reported that the chance of a relationship's leading to marriage increased if the partner matched their standards for important qualities in a mate. Conversely, the chance decreased if

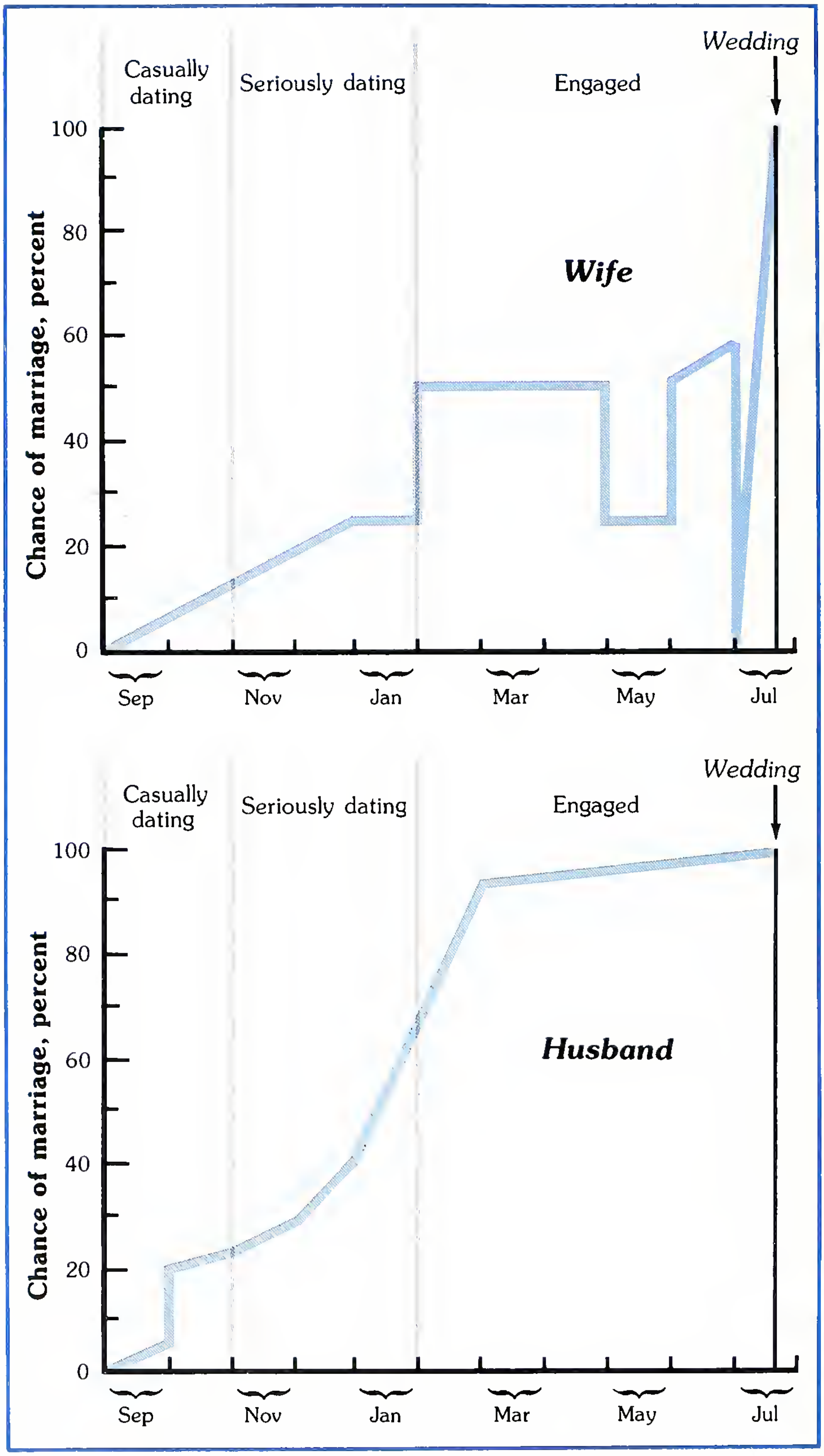


Fig. 1. The chance of their relationship leading to marriage, as perceived by a recently married couple. During his interview, the husband charted a relatively smooth, steady transition from the first date in September to the wedding in July. During her interview, the wife recalled ups and downs in their relationship before the wedding day. Information gathered from interviews with married couples may help to establish a link between marital success and the way courtships evolve.

those standards were not met. Respondents said things like, "I realized she was everything I ever wanted in a wife — domestic, warm, reliable," or "I was worried he was too happy-go-lucky all the time to be a good husband."

Men and women also have standards for what the relationship itself should be like. As one man who had temporarily broken off his engagement said, "I wasn't feeling what I thought I should be feeling if I was in love. There were no bells ringing or anything. My feelings didn't fit the script in my head for being in love."

The qualities attributed to a partner or to a relationship may exist in a person's mind, but may not be an accurate assessment of objective reality — a fact that is often discovered belatedly after marriage. For instance, partners may perceive that their values, goals, and interests are similar when actually they are not.

A strong predisposition towards marriage or against it is another important intrapersonal explanation for why turning points occurred. For example, a strong desire to be loved or to get married or the wish to overcome past romantic hurts can predispose partners towards serious involvement. Similarly, predispositions against intimacy and marriage can hamper courtship.

Data from the study show that partners who mention a positive inclination towards marriage or other intrapersonal factors have short, fast courtships. On the average, these relationships accelerate to engagement within three to five months.

The relationship itself is often mentioned as a reason for moving towards marriage or away from it. These relationship reasons emerge from the interaction between partners. Conflict and the disclosure of personal information are typical events in a relationship that may precipitate a shift in the chance of marriage. Other events with special meaning may include gift giving or mutually redefining the relationship, for instance by agreeing that "we are in love" or that "we have broken up."

Many respondents reported spending considerable time together early in courtship. They said that enjoying this time helped to escalate their involvement. But even a lack of interaction often served to increase involvement. One woman said, "He was just a friend in the beginning, or at least I thought he was. I didn't realize I was emotionally involved until I broke up with him. It was only for three or four days, but it made me realize how much I cared."

Sexual involvement and a partner's giving up a job or vacation are examples of events in the relationship that can have special significance. In one case, the fact that an anticipated event did not occur led to a major dip in the chance of marriage during the six-year courtship: "I really expected that we'd get engaged for my birthday. I was so disappointed that I didn't get a diamond. It made me feel I was more interested in him than he was in me."

The social network, or interaction with third parties, is another category of reasons that influences the decision to wed. For instance, one young husband and wife said their chance of marriage went up and down with her parents' attitude towards the courtship. Although the couple wanted to marry early in their courtship, the chance of marriage dropped to zero because, as the wife said, "My parents were giving me a lot of hassles." After the parents separated them, the boyfriend "kidnapped" his partner. The parents finally gave their approval to the marriage with the admonition, "I hope you work as hard to make it work as you did to get together."

In some cases the influence of the social network goes beyond family and friends. One couple broke off entirely for several months because, they said, "Our religious counsel agreed it was a wise decision."

Circumstantial reasons are the final category taken into account. Financial status, job security, car accidents, and sudden illness are examples of virtually uncontrollable life circumstances that may affect the decision to marry. One relationship escalated to 100 percent for the following, somewhat unusual, reason: "The weather was nice then, and Bill and I noticed that we get along better in nice weather than in wintertime. So we decided it was a good time to get married."

Data from the study show that circumstantial reasons play a significant role in moving rocky courtships that average more than five years in length towards marriage. An external event may give a final push to partners whose relationships have little momentum of their own.

Forces at work during courtship. The view that people select a mate by objectively evaluating the quality of the match is not well supported by our data. The studies demonstrate that forces within a relationship and outside of it affect the degree of commitment.

Furthermore, some of these forces cannot be controlled directly. A lack of conscious decision-making does not necessarily have negative consequences, however. Because people in the throes of romance may idealize their partners and may not get to know them well, they probably are not in a position to evaluate realistically their goodness-of-fit as a couple.

What, then, is the link between marital success and the reasons that courtships evolve? Two collaborative studies are under way to address this question. The reasons for shifts in the chance of marriage as seen by men and women in general and by partners in the same couple are being studied. So far the data indicate that men and women offer different explanations. Furthermore, partners often agree on when a turning point occurred during courtship but less frequently on why it happened. Still to be examined is whether disagreement bears on happy and unhappy marriages.

Also being investigated is whether marital success is associated with the reasons why relationships evolve to marriage. These studies will provide much needed information for helping to prevent marital distress.

Catherine A. Surra, assistant professor, Department of Human Development and Family Ecology

Education and One-Parent Families

Sheila Fitzgerald Krein
and Andrea H. Beller

A sizable and rapidly growing proportion of American children live in single-parent families. By 1982 more than a fifth of all children and half of all black children under 18 years of age were living with only one parent, almost always the mother. From 1970 to 1982 the percentage living in female-headed families increased 68 percent, while the percentage living in married-couple families decreased 21 percent.

The number of children living in one-parent families will continue to rise in the years ahead. It is now projected that nearly half of all American children will live for some time in a single-parent family and will spend a longer period of their childhood than was common in the past with only the mother.

This trend has aroused social concern for several reasons. Foremost among them is that female-headed families tend to be economically deprived. Resources such as money and time are typically in short supply. The median income of female-headed families in 1982 was less than half that of married couples. Furthermore, single mothers often have little time to spend with their children. Carrying a dual burden, these women must support the family by working outside the home but must also shoulder full responsibility for the housework and child care, which married couples share to some degree.

Adult family members generally work in both the labor market and in the home. Work outside the home provides the money to buy market goods and services. These in turn are used during the time at home to produce healthful meals, prepare for vacations, and develop the human capital of the children. Defined as the skills, knowledge, and abilities that an individual possesses, human capital is built up through investments made by parents or through formal education and training programs.

Study of education level. Life in a single-parent family differs considerably from child to child. For example, the length of time spent in such families varies, and children are of different ages when the experience occurs. A child's education and other long-term effects are likely to be influenced by the child's age and the length of time spent in a one-parent family.

The purpose of the research study reported here was to determine whether living in a single-parent family had any significant effect on the education attained by young adults. The data we used were collected for the Center for Human Resource Research, which drew upon a national, longitudinal sample of more than 2,500 men and women who were between 26 and 38 years of age in 1980. First interviewed in 1966, respondents and their mothers were members of either a two-parent family or of a single-parent family headed by a female. Single-parent families headed by a male were not studied because there were too few of them.

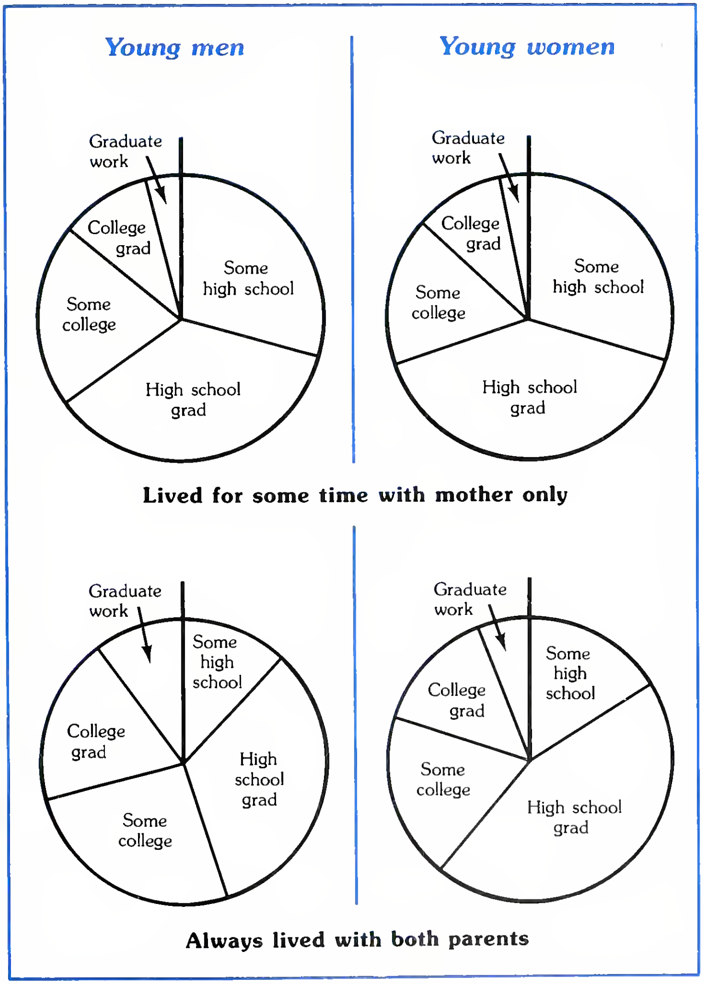
Background information. About 25 percent of the young men and 27 percent of the young women in the sample had lived for some time (an average of 7 years) with only their mother. They had more brothers and sisters than did the children from two-parent families and were more likely to be black and from the South.

The men from one-parent families completed 12.1 years of schooling, compared with the 13.5 years for men from two-parent families. Looking at the figures a little more closely, we find that about 72 percent of the young men from one-parent families completed high school, compared with about 88 percent of their counterparts (Fig. 1). Only half as many men in the first category completed a bachelor's degree or went on to graduate school as did those who lived with both parents.

For the young women in the study, family structure made somewhat less difference in their level of education (Fig. 1). Those from one-parent families completed 12.1 years of schooling, compared with the 12.8 years for women from two-parent families. Seventy-one percent in the first category completed high school; of those, 13 percent finished college. Eighty-four percent of the young women from two-parent families completed high school, 20 percent of whom earned bachelor's degrees.

Several features of the family background are salient. The mothers and fathers of children who had lived for any length of time in one-parent families had about one year less education than did the parents in married-couple households. Fewer reading materials were available in the one-parent households. A larger proportion of mothers who headed single-parent families worked during their children's first 18 years. During the young adults' high school years, family income also differed by family type. For one-parent families, the total annual income in 1966 was about \$6,000, compared with \$9,000 for the two-parent families.

Fig. 1. Level of education attained by young men and women in the sample. By age 26, the young men who had lived for some time in one-parent families had completed significantly fewer years of schooling than their male counterparts from two-parent families. The gap was narrower for young women in the two groups.



Effects on education. Using statistical methods, we made adjustments for family income, the mother's past employment status, race, and education of the mother and father. We found that living in a one-parent family significantly reduced the educational attainment of young men but not of young women. We also found that the length of time lived with one parent matters, but only for young men. The greater the number of years they lived in a single-parent family, the fewer the years of schooling completed.

A child's age when living with one parent also matters. The preschool years appear to have been the most sensitive for both the men and the women in our study. Those who had lived in one-parent families as preschoolers ultimately completed fewer years of school than did those who had lived with both parents. However, living in a one-parent family during the elementary and high school years did not affect the level of education.

One conclusion of this study is that, educationally, young men are hurt more than young women by the father's absence from the home. Psychologically, too, boys are more affected than girls, as research in psychology has shown. An important difference between these two lines of research should be noted, however. While psychological research has focused on children's emotional adjustment a few years after divorce, our study has looked at educational attainment in the adult years.

Improving the odds. Living with only one parent generally has a negative effect on the educational attainment of young men. Yet, other

Providing an adequate supply of reading materials in the home is one way that single parents can help create a stimulating learning environment for their children.

factors appear to mitigate this effect, as our research findings indicate. An adequate family income, mother's and father's own education, and greater availability of reading materials in the home also enter the picture and can raise the educational level of children of both sexes.

Finding ways to improve the low income of single-parent families is vital. More and larger child support awards are an important component of the solution, along with stricter enforcement. Policymakers should figure in a mother's time as well as her earnings, if any, when revising income support programs.

Programs to improve the job skills of women heading one-parent families are important. Although a few programs for displaced homemakers exist in Illinois to assist mothers in coping on their own after divorce or death of the spouse, more programs of this nature are needed. We also need to convince young women that they should develop job skills and get a better education because they will probably have to provide for themselves at times.

Improvement in the education of the parents along with an ample supply of reading materials in the home can encourage a child to learn. Parents are apt to provide a stimulating learning environment for a child if they extend their own education through formal classroom instruction or informal sessions such as those offered by the Illinois Cooperative Extension Service.

The findings of our research point to the preschool years as the most important. During these years the parents play a major role in making human capital investments in their children. Good and affordable day care with an educational component is essential for mothers who work, and in particular for those who head one-parent families. Once children are in school, teachers take on much of the parent's educational role. Children, especially those in one-parent families, should be encouraged to take advantage of library and other community programs.

Parents, teachers, and policymakers need to be aware that living in a one-parent family can have a negative influence on the educational attainment of children and that boys are affected more than girls. Now that more children than ever are living in one-parent families, the social stigma is beginning to lessen. People in charge of educational programs and community resources are finally recognizing this type of family as one of their target audiences.

Sheila Fitzgerald Krein, formerly Extension specialist in family economics, and Andrea H. Beller, assistant professor of family economics

In Progress

Three nutritionists win national awards

Three faculty members in the College of Agriculture recently received national awards for their research in nutrition. Richard M. Forbes was recipient of the Borden Award in Nutrition, provided by the Borden Foundation and the American Institute of Nutrition. The award was granted for his contributions to our understanding of mineral metabolism, factors affecting the function and utilization of minerals, and the nutritional roles of magnesium, zinc, calcium, phosphorus, nickel, copper, and lead.

John A. Milner was this year's recipient of the Bio-Serv Award in Experimental Animal Nutrition. This award was offered by the Bio-Serv Company and the American Institute of Nutrition. Milner has distinguished himself in the areas of arginine metabolism, quantification of amino acid requirements, and the antitumorigenic role of selenium. He is also director of the Division of Nutritional Sciences and an assistant director of the Illinois Agricultural Experiment Station.

Mary Frances Picciano was also recipient of a Borden Award for outstanding research in nutrition. Sponsored by the Borden Foundation and the American Home Economics Association, the award was given in recognition of her research contribution to the fundamental nutrition of infants and children. Among her many research endeavors, Picciano has examined the trace minerals, lipids, and other constituents in human milk and examined the nutritional status of infants fed human milk or commercial formulas.

Tillage practices to conserve soil

With all the worry over soil erosion, farmers may be uncertain about which of the many tillage systems may suit them best. To help them decide, agricultural engineer J. Kent Mitchell has been studying the erosion effects of different tillage practices for corn and soybeans.

In the study, the following five tillage systems were used on slopes of 4 to 6 percent: conventional, ridged, sweep-plow, disk, and no-till, all with rows on the contour. Conventional, ridged, and no-till were also used with rows up and downhill. Simulated rain was applied to the plots at a rate of 2.5 inches per hour immediately after planting and when the canopy cover was 25 percent.

In corn following soybeans, the contoured no-till plot had the least amount of soil loss. On the up and downhill rows, soil loss even on the no-till plots was greater than that on the contoured areas. There was no soil loss from ridge tillage on the contour for the first 1.3 inches of rain, but the loss was very high with additional amounts of rain.

Canopy cover had little effect on soil loss on the contour plots. But on the up and downhill rows, the loss was greater with 25 percent canopy cover than it was right after planting.

In soybeans following corn, all systems had less soil loss at planting than in corn following soybeans. These results show that surface residues from the corn crop help reduce soil erosion.

A posh environment for upper-crust hybrids

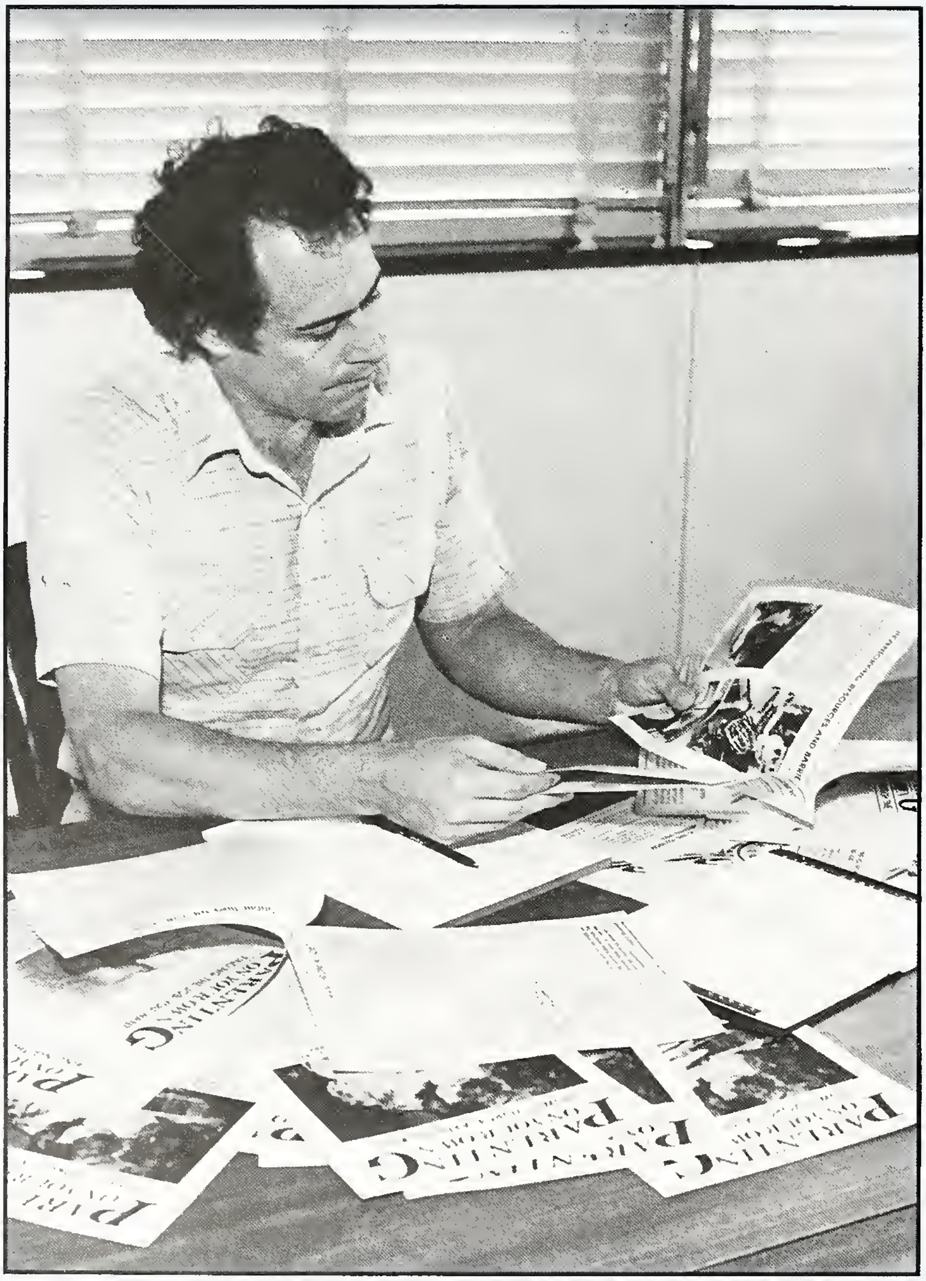
The profit possibilities of a high yield environment haven't been evaluated yet, but corn yields have been increased by 97 to 135 bushels per acre. Plant geneticists Robert Lambert and John Dudley have been studying corn bred for production in a special environment over the last eight years. The purpose of the study was to develop the environment and evaluate how well the hybrids adapt to it.

Production practices for a high yield environment include a late April planting date and a corn-soybean rotation, with fall-plow tillage after corn and chisel-plow tillage after soybeans. Sutan+ and atrazine are used for weed control, and 300 pounds of phosphorus and potassium along with 400 to 500 pounds of nitrogen are applied annually. Corn is planted at a density of 32,300 plants per acre at 20-inch row spacings; irrigation is used as needed.

The average yield of the thirty hybrids used in the study was 97 bushels per acre above the 1979-1983 Illinois average of 112 bushels. The average of one hybrid (B77 x B73) was 135 bushels above the state five-year average for the same period.

Successful production of corn in a high yield environment requires more inputs and more intense management than needed for normal production. Although the results may look promising, Lambert and Dudley warned that programs for producing corn in such an environment are not designed for the typical farm.

Newsletter for single parents



Bob Hughes is pictured here evaluating pilot issues of the newsletter *Parenting on Your Own*. Sixteen issues are now being prepared for publication and will be released to the general public sometime next year.

The impact of divorce on children and parents has prompted Home Economics Extension to launch a major effort to strengthen single-parent families. A central part of this effort is a newsletter titled *Parenting on Your Own*, which Robert Hughes, Jr., and Jane Scherer have developed. Scheduled to be released within the next year, this 16-issue publication will be available throughout the United States.

The newsletter is designed primarily for those who are adjusting to parenting alone. The focus is on ways to meet the challenges of everyday living. Through the use of photographs, quotations from single parents, and current research information, the newsletter conveys the message that one-parent families can be healthy and adjust successfully.

Many critical topics will be discussed, among them, self-esteem, social support, loneliness, time management, and stress. To help deal with financial concerns, several issues will be devoted to budgeting, credit, and job-finding skills. Also, to help parents cope with their children, many child-rearing topics will be addressed, including child-care arrangements, discipline, and shared parenting. Two issues will be devoted to examining the effects that divorce has on children and ways that adjustment can be fostered.

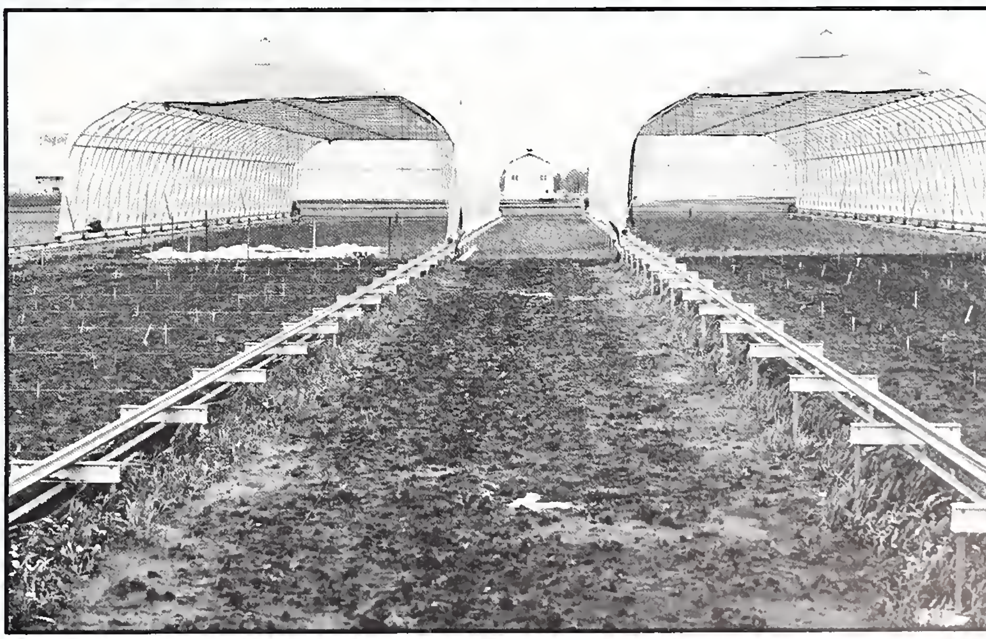
Parenting on Your Own will be distributed by county offices of the Cooperative Extension Service and by the Department of Human Development and Family Ecology, University of Illinois at Urbana-Champaign, 528 Bevier Hall, 905 South Goodwin Avenue, Urbana, Illinois 61801.

Crop yields and acid rain

Acid rain is a problem that concerns everyone — farmers, environmentalists, and consumers. One aspect of the problem, namely, the effects of acid rain on corn and soybean yields in Illinois, was studied by agronomists Wayne Banwart, John Hassett, and Bruce Vasilas. The research team found that, although some crops may show yield decreases due to acid rain, the overall effect on production is minimal.

Crops were allowed to grow under normal circumstances, except when it rained. When a switch was triggered by natural rainfall, rail-mounted greenhouses moved over the crop. Simulated rainfall of different pH levels was then applied to crops within the structures. The pH levels ranged from 3.0 (most acidic) to 5.6 (no acid).

Of the two varieties of soybeans used (Amsoy and Williams), Amsoy yields showed an overall decrease of 6 bushels per acre between pH 5.6 and 3.0; Williams yields showed no significant decreases. The largest decrease in Amsoy yields came between the pH levels of 5.6 and 4.6. Neither of the two corn varieties in the study (B73 x Mo17 and Pioneer 3377) was significantly affected by acid rain.



Throughout the growing season, mobile greenhouses mounted on rails moved automatically into place over test plots to block out natural rainfall. Inside the structure, simulated acid rain of various pH levels was applied to the crops.

University of Illinois at Urbana-Champaign
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Urbana, IL 61801 • Publication

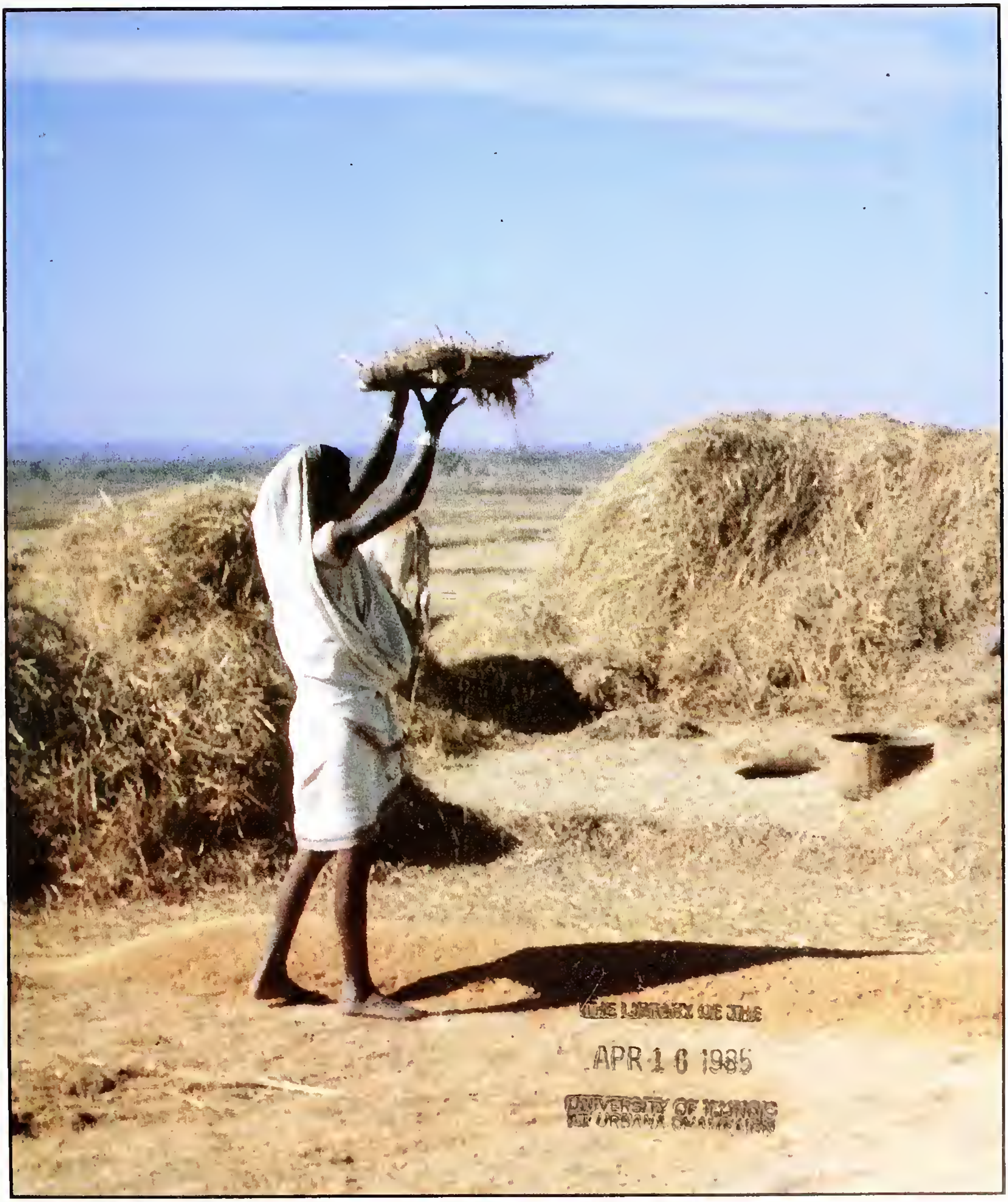
Illinois Research

Winter 1985

International agriculture: who benefits?

Illinois Research

Agricultural Experiment Station
Winter 1985



College of Agriculture, University of Illinois at Urbana-Champaign, Volume 27, Number 1

1985 - Directions - 1995

New Directions for International Programs and Studies

During the 1970s, while the United States was absorbed in political crises and domestic discontent, interest in things international declined on most campuses across the nation. Recently, however, language and international studies are again attracting the scholarly attention merited by a nation as rich and powerful as ours. But even during the slump, the University of Illinois pursued its international efforts. As a result, we are well-positioned to take advantage of new programs and funding as they become available at federal and state levels.

The development of international and area programs in the United States during the 1950s and 1960s reflected certain irrational institutional barriers. Area programs dealing with the Soviet Union, Eastern Europe, Latin America, and China, for example, evolved primarily within colleges of arts and sciences. Colleges of agriculture, however, were not brought into these programs. As a result, area studies were and remain seriously deficient when it comes to the study of agricultural production, rural sociology, agricultural economics, and related fields.

Colleges of agriculture, on the other hand, developed during the 1950s and 1960s under the influence of U.S. aid and trade. They developed expertise primarily in certain Third World areas that received considerable U.S. aid, and they ignored the rest. Most land-grant institutions also failed to develop expertise about the centrally planned economies of the Soviet Union, Eastern Europe, and China, mainly because we conducted little if any agricultural trade with them.

Differing interests and diverse sources of funding led to the further compartmentalization of programs in law schools, colleges of education, and other units. Because of academic barriers among colleges and disciplines, considerable unevenness exists today in international programs and studies on U.S. campuses.

One of the principal aims of the office of International Programs and Studies at the University of Illinois is to lower these barriers by integrating research and teaching in international affairs. The breadth of topics covered in this issue of *Illinois Research* illustrates the extent to which the effort is under way. The next step is to encourage greater cooperation among colleges on this campus.

James R. Millar, director, International Programs and Studies, and Associate Vice Chancellor for Academic Affairs

The Cover

In India as in other developing countries, women are indispensable to agriculture. With her sari tucked up, the young woman pictured on the cover carries a basket of straw from threshing. The College of Agriculture has research and educational ties with India and other Third World nations. As farmers' incomes rise in many of these countries, their demand for food imported from the United States also rises. Furthermore, our scientists benefit through the exchange of scientific information and materials that can be adapted to agriculture in Illinois.

"At a time unlike any in the past, we must envision the future."

Illinois Research

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International Agriculture

Letters

To the readers:

Recently we asked for subscribers' reactions to *Illinois Research* and suggestions for improving our coverage of Experiment Station activities. We want to share some of these comments and suggestions with you. Although we cannot incorporate all of your ideas into the publication, we will try to do so wherever possible. Letters to the editor are always welcome. Please keep them coming.

Sheila A. Ryan, editor

Comments

I enjoy reading your publication. I feel it helps keep me abreast of activities other than the engineering and construction field.

Flossmoor, Illinois

A very useful and informative publication.

Argonne, Illinois

I particularly like the publication on foods and their relation to cancer.

Edelstein, Illinois

Your 25th anniversary issue was excellent and has been very useful in my classes to teach about technology in agriculture.

High school teacher, Concord, California

A very commendable publication for the taxpayer to see what his dollars do.

Greenfield, Indiana

Good publication! We should have continued our own similar publication, "Iowa Farm Science."

Ames, Iowa

A good publication! It helps me in my teaching and research.

Professor, East Lansing, Michigan

Excellent reference for ag science students. You relate pure and applied sciences better than most.

Librarian, Redwood Falls, Minnesota

I always enjoy reading *Illinois Research* and file it among my other research journals.

Professor, Las Cruces, New Mexico

Illinois Research is a great publication! You are doing a super job of informing the public of your work. The publication helps me do a better job of my duties.

Extension specialist, College Station, Texas

Donald A. Holt's article about agriculture and research was outstanding!

Provo, Utah

We enjoy the magazine for expansion of ideas and increasing awareness of what is happening. "New Uses for Starch and Oils" — tremendous!

Lovington, Illinois

I find the contents of *Illinois Research* both interesting and useful.

Stansted Mountfitchet, Essex, England

The articles are of great value to us researchers, students, and faculty. We are kept abreast of the new technologies as well as enriched.

Agoo, La Union, Philippines

Based on user statistics, the journal is highly in demand by researchers.

Librarian, Naawan, Misamis Oriental, Philippines

Thank you for a very useful journal. Keep up the good work.

Uppsala, Sweden

I find this information very useful, especially for agronomists who are in the field. This gives us an update of what's going on at the research level.

New Brunswick, Canada

I am very impressed with your publication. Keep up the good work.

Professor in veterinary medicine, Helsinki, Finland

Extremely interesting for us and timely.

Beersheba, Israel

Very good information and a great magazine with useful comments.

Torreon, Coahuila, Mexico

This is an excellent publication. Many thanks for sending it to me.

Professor, Palmerston North, New Zealand

Suggestions

Interested in good nutrition for helping heart disease.

Princeville, Illinois

I wish it was a monthly magazine.

Streator, Illinois

Better put more effort into converting toxic waste products, from a profit-motivated industrial economy, to useful or neutralized matter. We better face this reality before it's too late. *Illinois Research* has had some information on this matter, but maybe not enough.

Rockton, Illinois

I . . . look forward to future issues, especially papers on forages and their utilization.

Lafayette, Indiana

(**Letters** continued on page 30)

Ties With Other Nations — Who Benefits?

William N. Thompson

Illinois agriculture depends on educational, trading, and research partnerships with other nations, many of them in developing regions of the world. A complete world map has been provided on pages 14 and 15 as a guide to the location of countries discussed in this issue of *Illinois Research*.

The international interests of the College of Agriculture have a long-standing history. For example, the 1874 graduating class at the University of Illinois included an agriculture student from Japan. A number of early faculty members received some of their graduate education in Europe. Before becoming dean of the College of Agriculture in 1895, Eugene Davenport spent a year in Brazil, where he helped establish an agriculture college.

Herbert W. Mumford, who became dean in 1922, had studied livestock conditions in Europe in 1897. Then after joining the animal husbandry faculty here, he visited Argentina and other South American countries to study the competitive position of the U.S. beef industry.

Nearly fifty years ago, Arthur T. Mosher, a graduate of the College, began working at Allahabad Agricultural Institute in India. His twenty years there were a forerunner of our participation in major programs to help India develop agricultural universities. About the same time, the College, in cooperation with the U.S. Department of Agriculture and with other states, began collecting soybean germplasm; today we have the world's most extensive collection. Later, after the maize genetics laboratory was established, work was begun on what has become the leading international collection of genetic stocks of corn.

Now that Illinois agriculture has become still more closely related economically and politically to agriculture in the rest of the world, our faculty and students have increased their participation in international research and education.

But why should a college of agriculture have a strong international dimension? Established to serve the nation and individual states, land-grant universities have an obligation to meet the needs of local farmers, farm input manufacturers and suppliers, farm product processors, exporters, and Illinois consumers generally. Meeting their needs and self-interest is directly related to international activities.

The College of Agriculture is involved in international research and education for four reasons, each of which merits discussion:

1. Major benefits accrue to production agriculture in Illinois and the United States.
2. International agricultural trade is expanded.
3. The research and teaching programs of the College of Agriculture and of the University as a whole are strengthened both on campus and off campus.
4. Our immediate and long-range humanitarian interests are served.

Benefits to our agriculture. Agriculture in Illinois and the United States rests on a foundation of scientific knowledge from other nations and the plant and animal species acquired from around the world. Scientific discoveries in Europe that benefited U.S. agriculture predated experiment stations in the land-grant system. None of our major commercial crops is indigenous to the United States. If plants had not been introduced from areas such as South America and Asia, we would be dependent on sunflower, pecans, blueberries, and a few other crops. Similarly, none of our breeds of livestock, except for some crosses, originated here. What would Illinois agriculture

be like without animal breeds from Europe and soybeans from China?

But now that we have highly productive crops and livestock species, why the need for germplasm and other scientific interchange? With the ever-present hazards of insects and diseases, it is essential that we have access to germplasm from other environments as sources of resistance. In fact, we need to accelerate our efforts in identifying cultivars having resistance to certain pests that may pose a threat to new varieties.

Many foreign countries are currently developing agricultural universities and research institutes with a cadre of first-rate scientists. Their goal is to increase production of food, fuel, and fiber for their own people and for export to earn foreign exchange. Their research contributes to the basic knowledge of agriculture and often helps solve Illinois problems.

We can maintain our competitive edge in research and education only by cooperating and communicating with such organizations around the world. We are in fact doing so under agreements with selected universities and research institutes. Our faculty members and graduate students are researching problems of mutual interest on campus and in cooperation with national and international research organizations and technical assistance projects. Participation in international conferences held both here and abroad is also encouraged.


A professor at the University of Illinois instructing a foreign student in agricultural entomology. Faculty members, students, and farmers all benefit from the exchange of scientific and educational materials.

Expansion of foreign trade. High production alone does not ensure a profitable agriculture. Good markets are an essential ingredient. But expansion of the U.S. market has slowed, now that our consumers are relatively well fed and the population growth rate has declined. Therefore, foreign trade has become crucial if agriculture is to prosper. As the leading agricultural export state, Illinois in particular needs foreign trade, which contributes to employment and foreign exchange earnings.

Up until recently the developed countries of Western Europe and Japan have provided the best markets both for farm commodities and for U.S. manufactured goods. Here too, however, the demand for U.S. farm products has slowed as production in those countries has risen and as their consumers, like ours, have become relatively well fed.

Low-income, developing countries have now become important trading partners of the United States. They offer tremendous potential for expanding our exports. These countries have large populations that spend a high proportion of their increasing income for food. On the other side of the coin, these countries are valued suppliers of noncompetitive commodities such as coffee, cocoa, some strategic minerals, and other materials.

An accelerated growth in their economies will help these countries generate the income needed to improve their meager diets through increased domestic production and food imports from abroad. This process is already under way; about a third of U.S. farm exports are now shipped to developing countries.

The College of Agriculture is contributing to the development of Third World countries by educating the young people who become leaders in research, education, and government. A fourth of our graduate students are from foreign countries, mostly developing ones. Technical assistance projects, supported by the U.S. Agency for International Development and United Nations agencies, promote the building of agricultural research and educational institutions.

The University of Illinois was among six universities that helped develop agricultural universities in India. These institutions now educate people for agricultural teaching, research, and extension right in their own country. Over the past two decades, Indian universities have been largely responsible for doubling food grain production and reducing the risk of mass starvation. With the rise in production, India has in turn increased its imports from the United States.

Strengthening the College and University. Working on technical assistance projects enables faculty members and students to add new dimensions to their educational, research, and extension activities. Once they have worked in different cultures and lived among the people, faculty members can relate better to students from foreign countries. Professors can then prepare our own Illinois students for international work based in the United States, in other developed countries, or in the Third World.

Valuable experiences are gained

through these technical assistance projects. For example, from them we gather useful information that can then be passed on to individuals and agencies involved in agricultural trade, business, and policy. Our research is strengthened through linkages with national and international agricultural research centers. In addition to learning about the technical aspects of agricultural production, we can study marketing systems and government policies that bear on improving trade among nations.

Humanitarian interests served. Beyond the economic self-interest of agriculture and the general economy, vigorous international activities serve the deep-seated humanitarian interests and values of farmers and other Illinois citizens. U.S. taxpayers support the Food for Peace Program, now thirty years old, which alone supplies more food aid to developing countries than is supplied by all other countries combined.

Many individuals and private groups assist in programs to alleviate poverty, malnutrition, and disease worldwide. The College and University are engaged in research and educational activities to understand more fully the technical, economic, cultural, and political issues associated with these problems. Increasing attention is being given to helping faculty, students, and other citizens understand the world food system and its importance to Illinois and the nation.

Throughout our history, U.S. agriculture has been closely linked to other parts of the world. The past ten years have brought energy crises, world economic recessions, unprecedented interest rates, fluctuating values of currencies, international money flows, and ups and downs in farm product exports. Clearly the agricultural world has become more complex and interdependent. The challenge is for the College to maintain and strengthen its role in a world-class University.

William N. Thompson, director of International Agriculture and associate dean, College of Agriculture, 1978 to 1984

Programs in International Agriculture

Bonnie J. Irwin

The Office of International Agriculture, part of the College of Agriculture, participates in several international programs and information systems. All of our programs are conducted cooperatively with other universities, governments, or international organizations.

INTERPAKS, International Program for Agricultural Knowledge Systems, was established in 1982. One of its goals is to support agricultural development through more effective application of technology and related information. Another goal is to improve the training and competence of agricultural extension personnel. INTERPAKS activities include research, technical assistance, short courses, and information services.

ZAMARE, the Zambian Agricultural Research and Extension Project, is oriented towards improving agricultural research and extension services for small-scale farmers in Zambia. The project seeks to alleviate Zambia's serious food problems caused by drought, foreign exchange shortages, and inadequate attention to agriculture. Southern Illinois University at Carbondale and the University of Maryland–Eastern Shore also cooperate in this project, which is sponsored by the U.S. Agency for International Development (USAID).

TIPAN, Transformation and Integration of the Provincial Agricultural Network, is another USAID-sponsored project. Its goal is to assist the Northwest Frontier Province Agricultural University in Peshawar, Pakistan, in serving small-scale farmers and rural households in the region. Faculty members from Southern Illinois University at Carbondale are participating with us in the project.

INTSOY, the International Soybean Program, is seeking to improve human nutrition around the world through the use of soybeans, a legume rich in protein and calories. Established in 1973, INTSOY offers many services to the world community through research, programs for cultivar testing and breeding, development of soyfoods, feasibility studies, consultancies, and publications. We also help organize regional and international conferences, training courses, and study programs.

In cooperation with the Illinois Natural History Survey's soybean entomology program, we manage two information systems. SIRIC, the Soybean Insect Research Information Center, maintains a computerized file on the scientific literature of arthropods associated with soybeans. The center also supplies bibliographic listings and copies of documents. ISAC, the International Soybean Arthropod Collection, is a computerized data bank and systematic collection of the arthropods associated with soybeans. Through this collection, soybean insect pests and their natural enemies can be identified rapidly.

In the Caribbean, our faculty members are working with USAID missions to organize agricultural communications and outreach projects at the University of Trinidad, and to implement national extension programs in Belize. This work is a cooperative program with MUCIA, a consortium of seven midwestern universities. We have also helped USAID prepare strategies for development assistance to a number of Caribbean nations.

The Office of International Agriculture provides an international dimension to the education of agriculture students at the University of Illinois. In addition, the office informs the public of international issues that are important to Illinois agriculture.

Bonnie J. Irwin, research associate, Office of International Agriculture

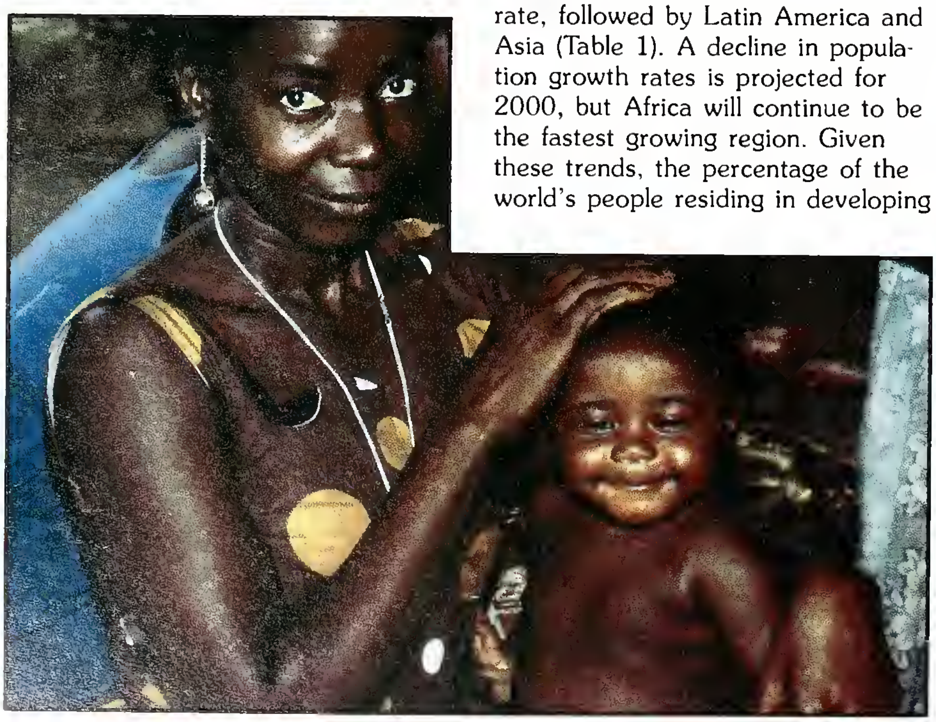
World Food Problems

Earl D. Kellogg

Concerns about the world food situation have received considerable international attention since the 1974 World Food Conference in Rome. Yet general agreement is lacking on the dimensions of the problem, workable solutions, and the role of developed countries in alleviating hunger.

The world food system is dynamic, and year-to-year changes are common. As a consequence, general patterns and trends are not well understood. For a better understanding of the current and possible future situation, some historical perspective and regional comparisons are helpful.

The United States is actively trying to ease world food problems. Americans need to understand the rationale for our involvement and its implications, because these problems will undoubtedly persist, and we will be called upon for continuing aid. In this article, I will describe the current situation and will analyze the reasons for U.S. involvement.



During the past fifteen years, per capita food production in Africa has declined at the rate of about −0.6 percent a year. Yet for the next three decades, Africa will probably have the highest population growth rates in the world.

World Food Situation

Food production. The production of food worldwide increased steadily at about 2.45 percent annually in the 29 years from 1954 to 1983. For the past decade, however, the pace has slowed to 2.23 percent annually. Since 1973, developing countries have achieved a more rapid increase (3.2 percent annually) than the 1.6 percent in developed countries (Fig. 1). (Developed countries are Australia, Canada, those in Europe, Israel, Japan, New Zealand, USSR, South Africa, and the United States. Developing countries are in Latin America and in the rest of Africa and Asia.)

Population growth. In mid-1984, the world's population reached about 4.76 billion people; 6.25 billion is projected for 2000. Population growth in developing countries continues to be considerably higher than in the developed ones. From the mid-1950s to the early 1970s, annual growth rates were about 2.5 percent for developing and 1.1 percent for developed countries. In 1984 these rates had declined to about 2.1 and 0.6 percent per year.

Africa has the highest growth rate, followed by Latin America and Asia (Table 1). A decline in population growth rates is projected for 2000, but Africa will continue to be the fastest growing region. Given these trends, the percentage of the world's people residing in developing countries will continue to rise — from 76 percent in 1984 to 80 percent in 2000. This change in distribution has important implications for world political and economic relations.

Per capita food production. From 1954 to 1983, the world's food production per capita increased at a slow rate of 0.57 percent annually and at 0.38 percent since 1973 (Fig. 2). Compared with developed countries, total food production in developing countries increased more rapidly, but so did their population. Consequently, the per capita growth rate of 0.54 percent in food production for developing countries was substantially less than the 1.05 percent rate for developed countries from 1954 to 1983. Between 1972 and 1983, however, growth rates for developing and developed countries were more nearly the same (0.75 and 1.09 percent). Of course the record varies considerably among countries and regions.

Selected developed regions. All developed countries and regions have increased their per capita food production in the past 29 years. The average annual growth rates have been higher in Eastern Europe (1.64 percent), USSR (1.42), and Western Europe (1.46) than in the United States (0.75) and Oceania (0.75), partly because the population has grown very slowly in Europe. In the past decade, however, the USSR has had almost no growth in per capita production, while Western Europe has continued to enjoy a rapid increase (Fig. 3). The USSR has also had large year-to-year changes in production. Because of difficult weather and problems in agricultural organization, annual changes of 8 to 10 percent are not uncommon. Given the Soviet Union's willingness to import food now, this variability is affecting world agricultural trade.

Developing regions. East Asia has had a particularly impressive record of increasing per capita food production since the early 1970s, while growth in Latin America has been more moderate (Fig. 4). The increase in South Asia and West Asia has been very slow during the past 29 years (Fig. 4). Steadily declining since

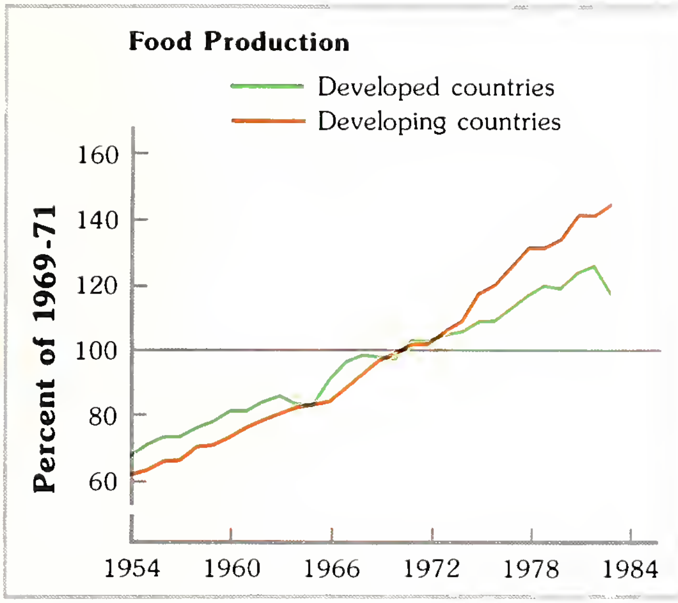


Fig. 1. Increases in food production worldwide, 1954 to 1983. Since 1973 the annual increase has been more rapid in developing than in developed countries.

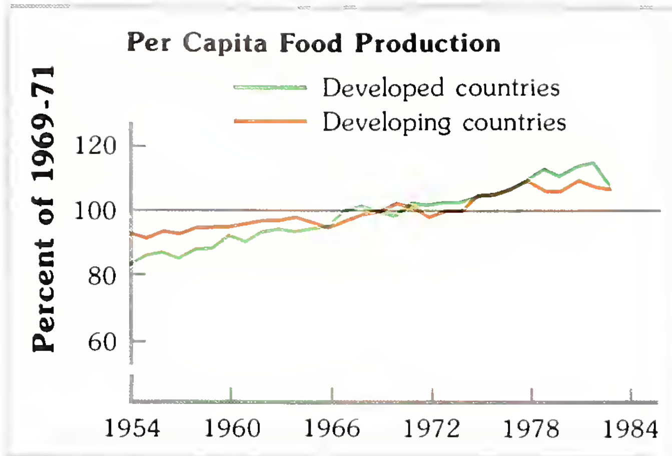


Fig. 2 Increases in per capita food production worldwide, 1954 to 1983. The rapid population growth rate in developing countries has all but cancelled out absolute gains.

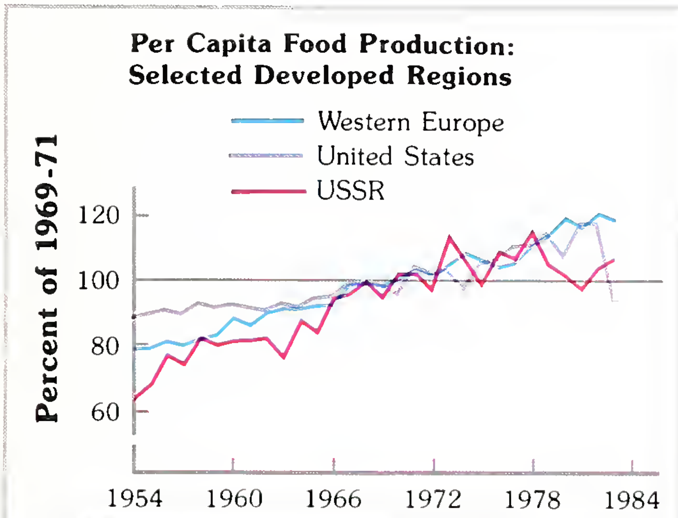


Fig. 3. Increases in per capita food production for selected developed countries, 1954 to 1983. In western European countries and Russia the annual growth rates have been larger than in the United States.

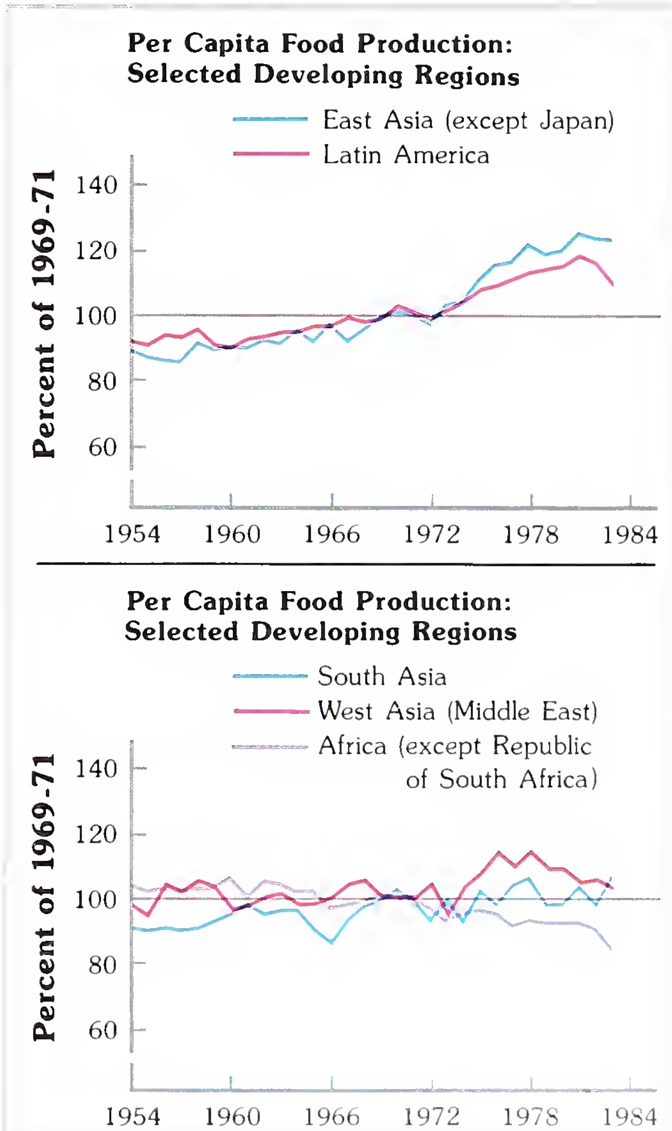


Fig. 4. Increases in per capita food production for selected developing regions, 1954 to 1983. Since 1968 the rate for Africa has dropped about −0.6 percent annually.

Table 1. ***Population Growth Rates in 1984 and Projected for 2000***

Region	1984	2000
	percent	
Developed regions	0.6	0.5
Developing regions		
Africa	2.9	2.3
Latin America	2.4	1.6
Asia	1.8	1.2
World	1.7	1.2

1954, Africa's per capita food production has dropped especially fast in the past 15 years (about −0.6 percent a year). Yet it is projected that Africa will have the highest population growth rates in the world for the next three decades.

Daily food supply. The Fourth World Food Survey, published by the Food and Agriculture Organization (FAO) in 1977, contains the most complete survey results available. According to the survey, if all the food produced worldwide had been distributed evenly, each person would have had 7 percent more calories than needed to meet normal requirements (Table 2). Africa and the Far East (South and East Asia) had the lowest per capita food supplies. Although calorie supplies did increase throughout the world, several regions still had sizable gaps to close before reaching per capita requirements.

Estimates of the number of people affected by hunger are extremely difficult to develop. The range is anywhere from 100 million to one billion people. According to FAO, about 25 percent of the people (446 million) in developing countries had food intakes below the critical minimum level in the mid-1970s (Table 3). The largest numbers of people, as well as the highest incidence of hunger, were found in South Asia and Africa. Given the decline in food production per capita in Africa since 1974, one can assume that hunger has increased there.

Other dimensions. Major progress cannot be made in alleviating world hunger and problems related to malnourishment with only a 0.57 percent annual increase in food supplies per person. The proportion of the world's population suffering from calorie malnutrition is probably holding steady if not increasing, but the absolute number of people affected is most certainly rising. Weanling children from ages one to four, pregnant and lactating women, and people living in harsh environments are the most seriously affected by malnutrition.

Famines induced by war and bad weather are often well publicized, but the largest hunger problem is chronic malnutrition among millions of people in several countries. People are hungry because they are poor, not because world food supplies are inadequate. Chronic hunger results when poor countries and poor families don't have the purchasing power to compete for the available food.

The general outlook for solving hunger problems is both encouraging and discouraging. Developing countries have increased their domestic per capita food production more rapidly in the 1970s and 1980s than between 1954 and 1970. Although still high, their population growth rates are declining somewhat. In the past decade, more attention at the international level has been given to alleviating world food problems.

On the discouraging side, the African food situation continues to deteriorate. In addition, many poor countries have extremely limited foreign exchange to buy food from the international marketplace. The serious, external debt problems of many developing countries have reduced their ability to import needed agricultural inputs and food.

Rationale for U.S. Involvement

Because world food problems affect all nations, rich and poor alike, their active participation is required to alleviate those problems. The rationale for bringing U.S. scientific and financial resources to bear on the problems has three aspects: humanitarian, political, and economic.

On the humanitarian side, 20 to 30 percent of the people living in developing countries don't have the food they need to grow and develop normally. Their per capita gross national product is $750, or twelve times lower than the $9,190 in developed countries. And the infant mortality rate of 9.4 per 100 live births is almost five times higher than the 1.9 per 100 in developed nations.

The political and economic rationale is equally compelling. The world is becoming one ecosphere. Individual nations must therefore understand and accommodate to this singular fact of survival. What other nations do affects the United States, and what we do affects them. This interdependence has inescapable political and economic dimensions. When the United States actively addresses world food problems, it is in

Table 2. ***Average Daily Per Capita Food Supply***

Region	Calories, percent of requirement[a] 1961-63	1972-74
Developed countries	124	132
Developing market economies	92	95
Africa	89	91
Latin America	101	107
Near East	93	100
Far East	91	92
Asian centrally planned economies	83	87

[a]An average value of 110 per capita is generally accepted for reasonable assurance that most people with low incomes have access to the calories necessary to meet the requirement.

Table 3. ***Estimated Number of People With Food Intake Below Critical Minimum Limit***

Region	Number below minimum, millions		Percent below minimum	
	1969-71	1972-74	1969-71	1972-74
Africa	70	83	25	28
Latin America	44	46	16	15
Near East	31	20	18	16
Far East	256	297	25	29
Developing countries	401	446	24	25

fact promoting its own self-interest. Our international, political well-being is directly affected by world hunger.

More than 75 percent of the earth's people live in countries where food problems often have high priority. North-south dialogues, international food security conferences, and debt summits for developing countries are important parts of the world political agenda. Political unrest in many countries often arises from malnourishment, poverty, and high food prices. Since the United States has an interest in the stable and just development of poorer countries, it is imperative that we make headway in easing food problems. Security and peace for Americans depend in part on peace and stability in the developing world.

Our economic interests, particularly in agriculture, are also at stake. U.S. agricultural exports are an important determinant of the future economic well-being of American agriculture. Although significant, our traditional export markets in Europe have a limited potential for growth. The Japanese market could expand substantially, but serious policy problems have not been resolved.

Most growth in markets for U.S. agricultural exports is likely to occur in developing countries and in the centrally planned economies. Between 1970 and 1983, the share of U.S. farm exports going to these countries increased from 34 to 46 percent (Table 4), while the share exported to developed countries fell from 66 to 54 percent.

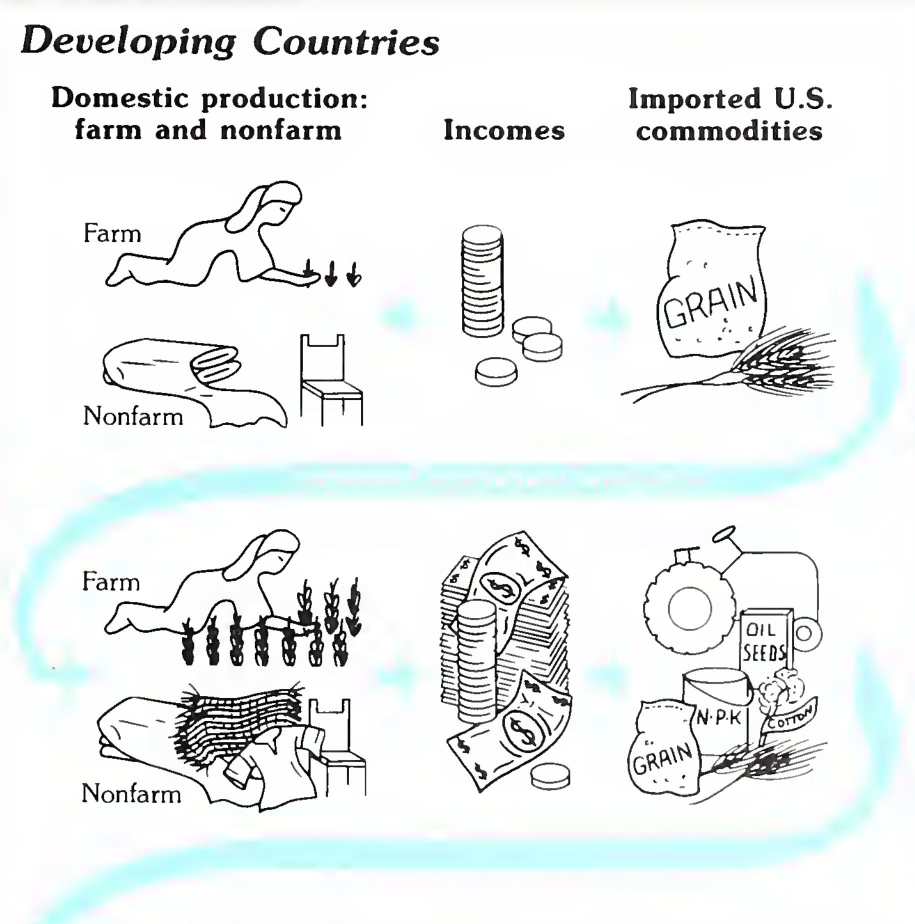
The developing countries with their expanding populations are clearly becoming important clients for U.S. agricultural products because their consumers spend a significant amount of their increasing incomes on food. However, the ability of these countries to import more agricultural products will be constrained by a lack of foreign exchange and the slow pace at which per capita incomes are rising. But if domestic food production in these countries does increase, these constraints will ease somewhat.

We are thus confronted with an apparent paradox: to become more important customers for U.S. agricul-

Table 4. ***Percent of Selected U.S. Agricultural Exports Shipped to Developing Countries and Centrally Planned Economies, 1982-83***

Commodity	Developing countries	Centrally planned economies	Total
Grains and feeds	53	11	64
Wheat and products	70	14	84
Rice	74	0	74
Corn	37	13	50
Oilseeds and products	25	4	29
Soybean meal	22	5	27
Soybeans	17	4	21
Soybean oil	86	13	99
Cotton	40	5	45
Animals and products	45	8	53
Total agricultural exports	40	6	46

Source: ERS, USDA: U.S. Foreign Agricultural Trade Statistical Report, Fiscal Year 1983. March 1984.



As agricultural production increases in Third World countries, the income of farm people rises. At the same time, economic activity in the nonfarm sector is stimulated, thus helping to ease foreign exchange constraints. Farm and nonfarm people will spend significant amounts of their bigger incomes to improve their diets. With the greater demand for food and the easing of foreign exchange constraints, more food and agricultural inputs are likely to be imported.

tural products, developing countries must increase their own domestic food production. Many of the people in developing countries obtain their incomes from farming. Therefore, agricultural production must increase in order to improve the incomes of a broad segment of the population. Using much of that larger income, these people will then be able to improve and diversify their diets.

Often, too, increased domestic food production helps the nonagricultural sector in developing countries to grow more rapidly, thus stimulating the demand for food there as well. Development in this sector may boost the export of nonagricultural products and help alleviate the need to import similar goods. Both of these results serve to improve the availability of foreign exchange. Import demands for specific commodities may decline, however, if some developing countries increase their own production of the agricultural products they have been importing.

To sort out the net effect of these various influences, I have analyzed the increases in food production in developing countries and the changes in their agricultural imports. Food production indexes and changes in agricultural imports were taken from FAO data for the past 20 years from 69 developing countries.

The results are revealing: for every one percent increase in the domestic food production of these countries, changes in agricultural imports into these countries increased 1.37 percent. The relationship was positive and substantial between changes in domestic food production and all subcategories of agricultural imports such as food and animal products, animal and vegetable oil, and agricultural inputs. Therefore, an increase in agricultural production in developing countries generally means an increase in imported farm and agribusiness products.

An example of this relationship may be instructive. From 1970 to 1981, Brazil's agricultural production increased by 69 percent — a rapid rate by international standards. During those eleven years, the quantity of agricultural imports from the United States grew by 370 percent, or 14 percent a year, and their value by 920 percent.

U.S. agricultural exports to Brazil changed from largely government-supported food shipments in the early 1970s to almost exclusively commercial sales a decade later (Table 5). Even commercial exports of our soybean products jumped from $600,000 annually to $34.6 million during the same period. U.S. wheat and corn exports to Brazil grew especially rapidly during this time. Brazil's imports of our agricultural products increased on the heels of their improved domestic agricultural production, which contributed to development in the nonagricultural sector and to the increased availability of foreign exchange.

Table 5. ***Composition and Change in U.S. Agricultural Exports to Brazil, Selected Years***

Export category	Average of 1970 through 1972	Average of 1980 through 1982
	Thousands of U.S. current dollars	
Government-supported	48,798	570
Commercial	27,935	705,370
Total	76,733	705,940
Government-supported exports as percent of total	64	.08

For a number of reasons, then, improving agricultural and food production in the developing countries is important to U.S. interests. Compared with other institutions in the United States, colleges of agriculture in land-grant universities possess the largest set of scientific resources that can be used for agricultural development in developing countries. The U.S. federal government and international organizations have therefore turned to the land-grant universities for help in easing world food problems. These efforts benefit people living in poverty, improve the chances for world peace and stability, and also contribute to the prosperity of American agriculture.

Earl D. Kellogg, associate director of International Agriculture and professor of agricultural economics

A local market, St. Vincent. Through increased sale of farm products, farmers in the West Indies, as in other developing regions, can realize some gains in income. Increased income from farm and nonfarm production enables them to buy more food and other commodities from the U.S.

Overseas Markets for Illinois Farm Products

Susan E. Offutt

Illinois has long been involved in agricultural commerce outside its own borders. In the days when livestock herds were expanding, we sold increasing amounts of corn and soybeans for cattle, hog, and poultry feed elsewhere in the United States. More recently, Illinois has acquired trading partners around the world, including countries in the European Community, Eastern Europe, Asia, and Latin America.

The escalating involvement of this state with the international agricultural economy represents only one facet of the nation's ever more intimate economic relationships with the rest of the world. U.S. exports, both agricultural and nonagricultural, have grown in value from about $40 billion at the start of the 1970s to around $200 billion at the beginning of this decade. Over the same period, imports have also risen, from $45 billion to $245 billion.

Expanding trade relations, along with changes in the international economic system, have magnified the interdependency of nations' economies. These changes are reflected in floating exchange rates and the recycling of OPEC petro-dollars. Virtually unknown even ten years ago, economic summitry among world leaders is an acknowledgment of these closer links between economies and national policies related to fiscal and monetary macroeconomics.

Agricultural trade. The agricultural sector has accounted for an average 20 percent of the value of all U.S. exports during the past decade and a half. At the start of the 1970s, the United States sold $6 billion worth of agricultural commodities, mainly wheat, to other nations. By 1973, sales had climbed to $14 billion and by 1983 to $35 billion.

This sixfold increase in just fifteen years can be attributed to a combination of factors. First, much of the increase in terms of current dollars is accounted for by inflation. Second, bad weather in other parts of the world, coupled with an OPEC-induced jump in the price of oil, sharply pushed up the prices of all agricultural commodities in the 1970s; however, the quantities exported also increased by about 60 percent. Third, and particularly important for corn and soybean exports, the increasing affluence in Japan, Taiwan, and countries in Western Europe fueled the demand for livestock products. Derived demand for feeds was thus stimulated, and American corn and soybeans entered new and expanding markets.

Corn and soybeans together continue to be the leading U.S. agricultural exports. In 1983 corn and corn products accounted for about 16 percent of all agricultural exports, and soybeans and soybean products for 22 percent. Wheat exports were about 18 percent of the total.

In contrast, there was only a twofold increase in U.S. imports of agricultural commodities and products, which accounted for $16 billion worth of purchases. As a percentage of all U.S. imports, however, food and other agricultural commodities fell from 12 percent in 1973 to only 7 percent ten years later.

The main import category is vegetables, most of which come from Mexico and Latin American countries. Winter tomatoes are probably the best example of this trade. In 1983 vegetable imports cost $7 billion, or nearly half of all agricultural imports. Another $4 billion, almost a quarter of the total, was spent on animals and animal products, largely frozen meats from Australia and New Zealand. Coffee is the third largest category; in 1983 Americans paid producers in Latin America and Africa almost $3 billion. The next appreciable outlay — about $1 billion — was spent on fruits, mostly from Latin American and Asian growers.

The size of the overall U.S. trade deficit has been held down with the help of a consistently positive balance of trade in agricultural products. The export performance of the U.S. agricultural sector and the declining relative importance of agricultural imports produced a net surplus of $20 billion in 1983. Thus the deficit of $70 billion in nonagricultural trade was somewhat offset. A healthy agricultural export market clearly contributes not only to the well-being of domestic producers, but also to the national economy as a whole.

Illinois's role. Against this backdrop of accelerating international trade and interdependence, Illinois emerges as a pivotal player. Given the importance of our corn and soybeans as exports and as cash crops, it is not hard to understand why Illinois led the nation last year in farm exports. Almost $2.94 billion of Illinois products were reported sold overseas, along with another $2.85 billion from Iowa. Together the two states accounted for one-sixth of the $35 billion worth of U.S. agricultural exports.

These trade-share figures should be viewed with caution, however, because they are only estimates. At ports it is difficult if not impossible

Grain being transferred by loading spout into the hold of an ocean-going vessel. A healthy agricultural export market contributes to the economic well-being of the state and nation.

to distinguish commodities by state of origin. Consequently, the system used to determine state exports assumes that, for example, if Illinois produced 15 percent of the U.S. corn crop, then it also accounted for 15 percent of U.S. corn exports.

The size of these export figures can be put in perspective by considering Illinois agricultural imports from abroad. If the imports are allocated to states by population percentages, then Illinois with about 5 percent of the U.S. population would have absorbed some $820 million worth of imports last year. With these consistent allocation estimates, Illinois in its agricultural trade with the rest of the world runs a surplus of almost $2.1 billion.

As impressive as these figures seem, they belie the complex linkage between exports and the health of our agricultural economy. Now that exports are becoming an increasingly large component of farm sales, domestic markets are influenced more and more by events in the rest of the world. Poor weather and crops could force other nations into the international markets, thereby driving up U.S. prices both at home and abroad. Or, as the case has been more recently, stagnating income growth keeps these countries out of world trade.

In addition to variation in their crop yields, the agricultural policies of other countries can affect U.S. prospects. For example, the centrally planned countries of Eastern Europe as well as the Soviet Union may purchase imports primarily to meet internal goals; price is secondary. In the European Community, a variable levy system serves to insulate its domestic markets from world price movement. These insensitivities have caused problems for the United States as the world's largest supplier of corn and soybeans.

Unlike the markets in many other countries, our own domestic markets for corn and soybeans are unprotected from the price swings occurring in international markets. The United States functions as a residual supplier (a supplier of last resort) to the world, accumulating or liquidating stocks as foreign demand fluctuates. The burden of adjustment therefore falls on U.S. suppliers of feedstuffs and also on livestock producers, who use most of what is not sent abroad. It used to be said that when the United States sneezes, the rest of the world catches cold. Now, the reality of today's agricultural trade relations suggests that the causality might be reversed.

Outlook for the 1980s. After the heady increases of the 1970s, the rate of increase in the value and quantity of agricultural exports slowed and then actually declined with deepening world recession and the rise in the value of the dollar.

Between 1982 and 1983, exports fell off almost $5 billion, a decrease of more than 20 percent. Currently, there is no expectation of a significant rebound even in 1985. Indeed, it is difficult to be sanguine about the outlook for the 1980s and beyond.

Demand conditions in this decade, particularly for feed grains, will depend largely on income growth in the so-called newly industrialized countries such as South Korea and Taiwan. The demand for livestock products — along with the derived demand for feedstuffs — is very responsive to income increases. In many of these countries, a one percent increase translates into a greater than one percent increase in demand for livestock products. Therefore, income growth is ultimately the driving force of the feedstuffs trade.

The potential for increasing our sales to developed nations, such as those in the European Community, is rather more bleak. First of all, their domestic agricultural policies protect their own producers. Secondly, these countries have reached a level of affluence beyond which the demand for livestock products responds quite slowly to income growth, much as demand seems to have done in the United States.

But even if income growth does pick up over the rest of the decade, conditions in the world markets will probably be considerably more unstable than fifteen years ago, largely because the United States has become a residual supplier. Barring major changes in U.S. policy, Illinois producers will remain susceptible to the price and income volatility arising from foreign markets.

At the same time, corn and soybean production in Illinois will probably stay at about the same level. Projections show a possible corn surplus of one billion bushels by 1990 and 1.2 billion by the year 2000. Consequently, development of new markets either at home or abroad holds the most hope for Illinois growers.

The promise of value added. The bulk of Illinois agricultural exports is in the form of unprocessed commodities such as shelled corn and raw soybeans. Given the bleak prospects for increases in traditional markets, some experts have suggested that Illinois concentrate on processing products from these basic commodities. In that way we might capture the value added in production. For example, selling processed feeds such as corn gluten should be emphasized instead of simply selling shelled corn. Producing tofu and similar foods from soybeans might be another possibility. Value-added products might also provide jobs for Illinoisans in processing and packaging plants.

Will value-added processing be the salvation of Illinois agriculture? At this juncture it is of course too early to tell. Perhaps we could argue that this course seems the only one now open to the state and so it must be tried. Surely there are marketing opportunities for such products around the world.

A note of caution should be injected, however. Value-added products very often require fairly large labor inputs. But labor in the United States is more expensive than in other areas of the world, as the Japanese among others have demonstrated. Trying to compete could therefore be difficult under current conditions.

Furthermore, most nations would prefer that the value added in processing be captured by their own domestic economies. As an example, Spain imports raw rather than crushed soybeans for this very reason. On these same grounds, the United States itself has restricted value-added imports of processed raw materials from developing countries.

International markets are now inextricably a part of the Illinois agricultural economy. Governed by events in the agricultural sector, these markets are also influenced by macroeconomic fiscal and monetary policies affecting income growth. Consequently, the continued health of Illinois export markets depends on the health of the world economy and on the prices of its commodities. For at least the next decade, this interdependency means coping with increased price volatility and stagnant markets. Slack foreign markets also have serious repercussions on the sectors that provide support to the farm economy.

A return either to the isolation of the 1960s or to the rapidly growing markets of the 1970s seems unlikely. For the 1980s and beyond, increasing and stabilizing foreign demand would be ideal. However, doing so will depend on whether the commercial sector opens new markets for traditional and perhaps processed commodities. Concerted action will also be necessary to strengthen macroeconomies around the world.

Susan E. Offutt, assistant professor of agricultural economics

World Map


Greenland
Iceland
Alaska (U.S.A.)
Canada
United States
Mexico
Honduras
Belize
Guatemala
El Salvador
Nicaragua
Costa Rica
Panama
The Caribbean
West Indies
Venezuela
Guyana
Colombia
Ecuador
Peru
Brazil
Bolivia
Paraguay
Chile
Argentina
Uruguay
Denmark
Netherlands
United Kingdom
Ireland
Belgium
Switzerland
France
Italy
Spain
Portugal
Morocco
Tunisia
Algeria
Mauritania
Upper Volta
Senegal
Gambia
Guinea
Sierra Leone
Liberia
Ivory Coast
Ghana
Togo
Cameroon
Gabon
Cen. Afr. Rep.
Mali
Nigeria
Congo

Developed regions

Developing regions

Agricultural Policy in International Relations

Robert G. F. Spitze

When a third of the normal U.S wheat acreage was set aside from production under the 1983 PIK (payment-in-kind) program, consumers in Africa and farmers in Australia soon felt the shock. And when the Russian invasion of Afghanistan in 1979 shook international relations around the world, the impact touched farmers and agribusinesses here in Illinois. The world continues to shrink in terms of how far and how fast our nation's agricultural policies reach beyond our shores.

An ever changing world. Agricultural policy clearly affects more than farming, and international relations go well beyond diplomatic summitry. In today's world, the agricultural policies of nations are intertwined with their international relations. Our own rural communities and the nations of the world have become mutually dependent, a fact that imposes itself in three major areas: at local policy meetings, during national policymaking, and in our research and educational programming. When understood, this interdependence should influence the decisions we make in each area.

Why have American agricultural policy and international relations been drawn closer together? There are four compelling reasons.

First, agricultural trade has grown dramatically. The current value of U.S. agricultural exports jumped from an average annual compound rate of 5.3 percent in the 1950s to 19 percent in the 1970s. By 1980, 30 percent of all U.S. agricultural commodities were exported, thus earning a substantial net trade surplus that helped reduce the rising nonfarm trade deficit. Furthermore, compared with three decades earlier, U.S. exports in 1980 supplied more of the world's total agricultural imports and much more of the total for centrally planned Communist nations. Yet this surge has turned around just as dramatically in the past few years and has already fallen more than 20 percent.

Second, nations have become increasingly interdependent economically. In the past three decades, world exports of all goods and services have grown even faster than U.S. agricultural exports — almost a fourth again as fast (11 percent annual compound rate in current prices).

Third, the risk of global devastation has risen. With the development of contemporary weaponry, disagreements among nations could escalate to catastrophic violence.

Fourth, communication technology has mushroomed. As a consequence, the speed with which national policies impinge upon international relations has accelerated. Fortunately this very capability also permits swifter knowledge transfer so that the consequences of policies can be understood and conflicts negotiated more quickly than ever before.

Yet even while the world has been shrinking, agricultural policy has been expanding. In the early days of policy development, professionals and nonprofessionals alike equated farm policy with policy directed primarily to problems in the production of food and fiber. Gradually the purpose of this policy evolved into a broader agricultural policy. In recent decades, it has included issues of grain reserves, trade, public food programs, and even credit and research related to food security. Now that food has become an integral part of this policy, it is aptly known as agricultural and food policy.

This policy holds something in common with international relations. Both share a common origin in government. Not to be confused with the private decisions involved in farming and marketing, the word "policy" as used here refers to governmental decisions. In the United States, these arise from the participation of many individuals and interest groups, in contrast to many other countries where policies are shaped by authoritarian, single-interest governments.

Similarly, the term "international relations" here refers to decisions involving governments, some participatory and some dictatorial. Herein lies a potential for cooperation or for disaster. In the absence of a world government to reconcile country policies, the policymakers of separate national governments can seek for agricultural and food policies that will contribute to constructive rather than disruptive relations among countries.

Positive roles of policy. Domestic policies increasingly affect international relations. For example, when the United States provides hefty subsidies for agricultural exports, we strain our relations with competing exporting nations. The consumers of importing countries may at first welcome such policies, but in the longer term their own producers react negatively by resisting the uneconomic competition.

By the same token, when the United States erects sturdy barriers to normal, competitive agricultural imports with no obvious reasons of food security, relations are strained because of potential losses for our consumers and for producers of the trading countries. Both types of policy thwart comparative economic advantages. However, instead of focusing on the possible negative results of agricultural and food policies, let us identify some positive effects.

Secure and efficient production. For most of the two centuries of our agricultural and food policy, we have focused attention on improving the productive capacity of American agriculture. These efforts have ranged from the educational policy of the common schools provision of the Northwest Territory Ordinance (rural, section 16) to the Agriculture and Food Act of 1981. The flow of policy over the years fostered development of public research, education, family farm tenure, credit, land and water conservation, rural electrification, and price and income stability. These basic institutions, in partnership with others such as private property, contract, and markets, provide one of the most efficient and stable systems in the world for the production of food and fiber.

In fostering the system, U.S. pol-

icy has contributed security to our food supply over the years. Particularly in times of war and natural disaster, our secure supply has affected international relations. It has also affected these relations through dependable food aid — as mandated by Public Law 480 — to regions with chronic food shortages and through increased commercial exports. In general, both food aid and commercial exports have been a low-cost source of food and fiber for the world's consumers and a competitive inducement for all producers.

Efficient marketing and distribution. The partnership between U.S. public policy and private entrepreneurship has led to more efficient distribution and has thereby had a positive effect on international relations. The more efficient the marketing system, the better it transmits consumer wants to the producers who satisfy them. The same can be said for producers' costs being borne by consumers.

Through an improved system of U.S. production and marketing, farmers and agribusinesses gain by having markets for their products; consumers worldwide gain from a dependable supply of low-cost food and fiber; and foreign exchange earnings help balance the flow of trade.

Our economic development rested on growth of the U.S. agricultural sector. Every other nation is just as dependent as we are upon an adequate agriculture within its borders or upon advantageous relations with agriculture elsewhere. Without one of these agricultural bases, economic development flounders. Where policy fosters agricultural systems that are efficient, secure, and equitable, it contributes to positive international relations.

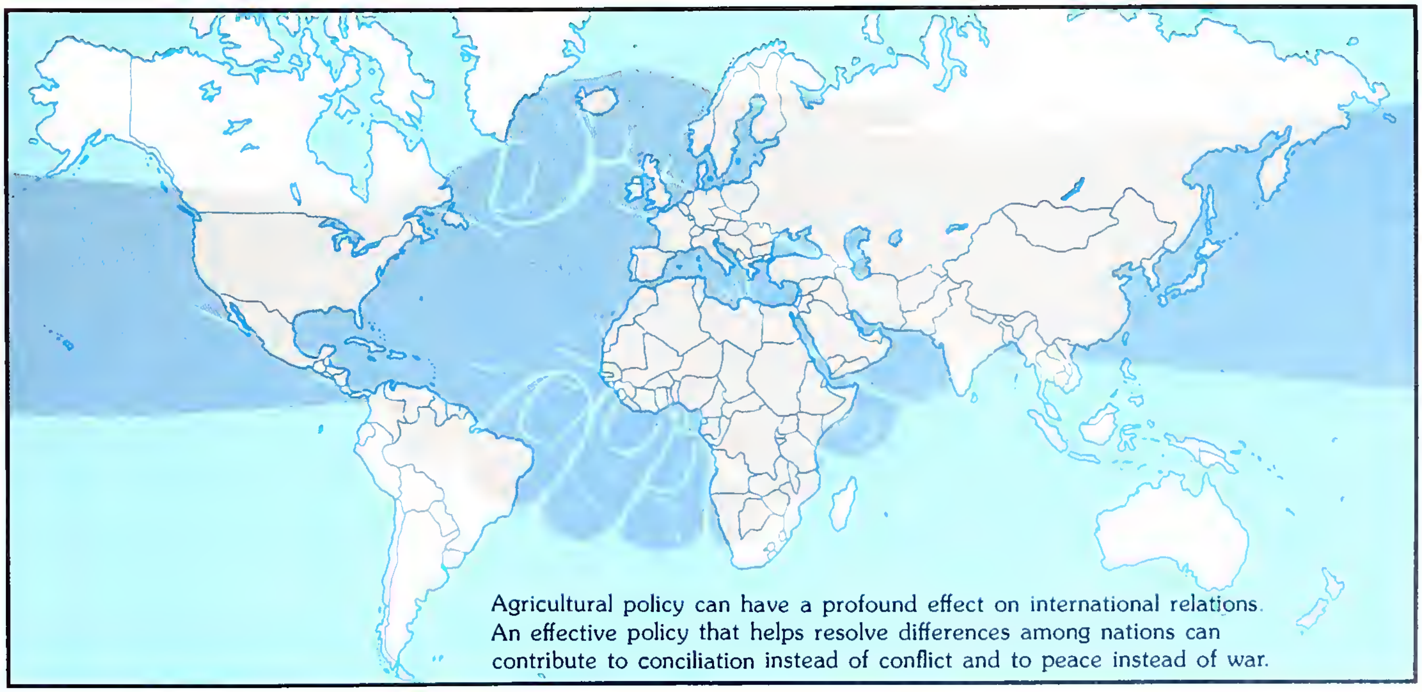
Economic stability. During the past half century, U.S. agricultural and food policy has tried to deal with farm and food prices, farmer income, balancing production with demands, food assistance, and grain reserves. But these issues have been difficult, persistent, controversial, and often unresponsive to the cumbersome tools of public policy. Yet the policies have continued because the public supports them and the problems themselves are intractable.

On the plus side, agricultural and food prices, incomes, and supplies in domestic and world markets are more stable than they would likely have been without the policies. In the United States, production was held down close to effective demand during the 1960s. Conversely, governmental stocks, by virtue of the new national grain reserves, counteracted pending shortages during the mid-1960s, the early 1970s, and then again at the beginning of the 1980s. A greater degree of stability for both farmer and consumer was the result.

Economic growth thrives on two conditions: stability to encourage investments and uncertainty to permit change. However, extremes of either can thwart sound development. In providing stability when disruptive instability exists, policies contribute to orderly economic development around the world and to improved international relations.

Knowledge and technology transfer. For more than a century, U.S. agricultural and food policies have encouraged the development of knowledge and technology and their dissemination. Being public, the results have been put to use not only in our own economy, but abroad as well. Some of our foreign assistance policies facilitated this transfer directly, while others fostered indigenous technology development abroad through institution-building.

Production, marketing, and agricultural stability in many nations have been affected and in turn have influenced food security, trade, and economic development. Policies can thus improve international relations by contributing to the development of knowledge, its application in new



Agricultural policy can have a profound effect on international relations. An effective policy that helps resolve differences among nations can contribute to conciliation instead of conflict and to peace instead of war.

technology, and its diffusion throughout the world's agriculture.

The process of public policymaking. As a rule, many people participate in agricultural and food policymaking in the United States. Governmental actions therefore represent a composite — usually a compromise — of the diverse values and the wisdom of many individuals and interest groups. This policymaking process itself contributes to the growth and efficiency of our agricultural and food sector. Interestingly, many public policies, among them agricultural research and education, have given life to this participatory system, which in turn has created other agricultural and food policies.

Transferring our understanding of the participatory nature of policymaking is an important kind of knowledge transfer. Policy has unquestionably contributed to improved international relations by helping nations solve their economic problems in accord with the expressed desires and needs of most citizens, instead of only a few.

Conciliation or conflict. Individuals, interest groups, and nation states will inevitably have differences of opinion. If unresolved through peaceful means, these differences can lead to confrontation and eventual warfare. The effects on agriculture, economic development, and civilization can be devastating. Policies profoundly affect the delicate process of social problem solving. The process is particularly crucial for agricultural and food policy because of its importance in development, in rural life, and in trade, the most common way that nations relate to one another.

Policy can contribute to conciliation instead of conflict and to peace instead of war. Policy makes these worthy goals possible by improving the production and marketing of food and fiber; by enhancing economic stability, security, and equity; by developing and diffusing knowledge and technology; and by allowing citizens to be represented in the governmental policymaking process.

Robert G. F. Spitze, professor of agricultural economics

Slash and burn agriculture as practiced in tropical Africa. The ash remaining after crop residues are burned contains important nutrients that are returned to the soil. At best, however, the top layer of soil is thin and wears out quickly, forcing farmers to move on to new areas after only a couple of years.

Cooperative Research Among Countries

James B. Sinclair and Leif H. Thompson

The development and sharing of agricultural technologies can no longer be limited by oceans and national boundaries. Roads to success must be two way and well travelled if we are to meet our obligations for world agriculture.

When farmers and people in agribusiness the world over exchange experiences and ideas with one another, production and marketing can be improved internationally. And when Illinois researchers are exposed to unexplored environments in the agriculturally developing world, their scientific imaginations are stimulated. The new perspectives thus gained can then be directed into further advances in Illinois agriculture, and resources unique to specific geographic areas can be used more efficiently.

Two major types of exchange have been taking place: one related to technology to improve production efficiency and the other involving genetic manipulation to improve the production capacity of crops and breeding herds. Both types of exchange are equally important and both will be critical in future interactions between our own scientists and those in other countries.

Crop research. None of the major crops now grown in Illinois is indigenous to the region. Maize came from South America, soybeans from Asia, wheat from the Middle East, and many fruits and vegetables from various parts of the world.

Soybean production is a good example of scientific exchange. Many years ago the crop was introduced into the United States with the cooperation of the Chinese. Through breeding, agronomic practices, crop protection, and so forth, U.S. agricultural scientists have improved on those original materials. Today, some of the soybean cultivars developed here are now being grown in the People's Republic of China.

Our use of imported germplasm is another example of scientific exchange. In some of the material that comes from Kenya, we have found the genetic source of modern resistance to wheat rust, and wheat developed in Nepal has a high lysine content. Continuing cooperation among nations will be necessary if we are to develop new crop lines and cultivars that can adapt to anticipated changes in our climate, food needs, pest problems, and production practices.

Terrace farming is common in many Asian countries. When working abroad, Illinois researchers can gain valuable insights into the efficient use of the resources available in a region. These new perspectives can then be adapted to agriculture in Illinois.

Many major pathogens, weeds, and insects affecting our crops first caused damage in other countries. We therefore have had to return to those areas where the crops came from. There, U.S. scientists seek germplasm to be used for further development of our own cultivars and varieties and to communicate with scientists who are working with the germplasm collections. For example, genetic resources for third-generation corn came from South America; and in the collections of wild, perennial *Glycine* species, our scientists may find sources of resistance to pathogens and pests. These wild species have been assembled from Australia, Fiji, Mariana Island, New Caledonia, Papua New Guinea, the Philippines, Taiwan, Tonga, and Vanuatu. The species were collected as a cooperative venture among scientists from those countries and from the United States, in particular from the University of Illinois.

U.S. scientists are also studying an estimated 10 to 20 percent of the germplasm in the People's Republic of China. The remaining 80 to 90 percent holds promise for further improvement in soybean cultivars. By exchanging populations of the soybean cyst nematode with nematologists in Asia, we hope to gain a better understanding of variability and races.

A vital resource of new and improved technology for pest control in the United States can come from countries where pesticides have not reduced biological control agents for diseases, weeds, and insects. The chance of finding such an agent for nematodes is better in Asia because the problem is native to that environment.

Another example of mutually beneficial research is the study of diseases. Before certain diseases become established on crops in this country, we can study them on the same crops in another country. Diseases and pests are often more serious in tropical areas, where selection for survival is made by nature as well as by humans. For example, resistance to several maize pathogens has been found in tropical germplasm. Now incorporated in U.S. hybrids, these characters provide resistance to the pathogens that cause northern corn leaf blight, southern corn leaf blight, corn rust, and maize dwarf mosaic.

Two new sources of resistance to soybean mosaic virus have been found in the Korean germplasm collection. Other diseases for which sources of resistance have been identified or are being sought are soybean rust occurring in Australasia and Latin America, Pyrenochaeta leafspot of soybean in southern Africa, soybean viruses in Turkey and Nigeria, and a leafspot of soybean in Nepal. All of the soybean cultivars currently used in the United States are susceptible to these diseases. In other countries where they occur, studies are being done on their biology, etiology, and epidemiology, and cultivars are being screened for resistance.

Illinois soybean scientists must work with scientists elsewhere so that if any of these diseases become established in the United States, we will be prepared to help our growers combat them. In turn, we must share the new technologies for pest control with those countries where the diseases were first detected. The knowledge gained from other countries also allows our scientists to make intelligent regulatory decisions.

A soybean researcher in the People's Republic of China. Exchange of genetic materials between the United States and China benefits agriculture in both nations.

An ear of maize infected with smut. Some diseases of maize can be studied on crops in Latin America before becoming serious problems in the United States. Often genetic resistance can be found and incorporated into U.S. hybrids.

Animal research. Scientists in most countries are encouraged to publish their research findings and to exchange information related to their academic achievements. However, the advent of biotechnology and genetic engineering may alter this free exchange. Research in these fields now requires expensive, sophisticated laboratories, which often must be guarded closely. The processes and end products may have to be tightly controlled, owing to the nature of the work and the potential for rather dramatic improvements in production. To realize a profit on their investment, investors may insist that the development of new vaccines, hormonal substances, or new strains of animals be kept secret.

The use of biotechnology in animal agriculture is a new frontier. Nearly every phase of animal agriculture may change dramatically during the next two decades. The most noticeable endeavors will occur in Western Europe and the United States, where scientific exchange has been fostered for some time.

In the past, animal science in this country has been more advanced than in most other countries. Consequently, we have helped educate animal scientists from elsewhere, especially from the Third World. We have also helped develop and improve their academic institutions. This work has been made possible to a certain extent by the stability of our economy and government.

Today, however, the European scientific community has matured, and the gap between their work and ours has closed considerably. Through biotechnology, countries whose land and other resources are limited can now realize a healthy boost in productivity without a concomitant change in inputs. For example, pharmaceuticals produced through genetic engineering for use in animal production are as well developed in some countries as they are here. Many companies in this field are based overseas or have foreign subsidiaries.

The United States continues at least to share the lead in statistics (data analysis systems), in research on animal breeding and nutrition, and in most areas of physiology.

Many of the leaders in these fields are from this country.

European scientists and producers excel in the application of selection systems in their swine and beef cattle industries. Many of our beef producers now import semen and purebred animals from European farms, thereby boosting productivity in U.S. herds. Although swine producers in Europe have an effective testing program, they are impressed by the growth rates of American swine. Our producers in turn have imported Landrace and Large Whites primarily for maternal traits and are interested in at least two very prolific Chinese breeds of swine.

In breeding stock and technology, the American dairy and poultry industries hold a significant edge over other countries. We have maintained this edge in large part because of the testing programs for genetic selection. Production efficiency approaches the upper limits of genetic capability of the breeding stock. In their sheep breeding flocks, however, other countries have achieved far greater levels than we have in production, genetic potential, and genetic diversity.

From these examples it should be clear that the international exchange of genetic material gives most countries the opportunity to improve their breeding herds. Improvements in the genetic potential of these herds can be realized by importing superior sires, unless health barriers for imports prove insurmountable.

Three major diseases that U.S. health officials and producers are concerned about are foot and mouth disease, African swine fever, and hog cholera. Before the gene pool of the world can be open to our scientists and producers, we must find more realistic and effective means than are now available for importing new breeding stock without the threat of introducing major disease problems.

The Booroola, a strain of Merino sheep raised in Australia, may make an important contribution on two counts. First, the noteworthy prolificacy of the Booroola appears to be controlled primarily by a single gene rather than by the far greater number of genes that usually influence this trait. Finding the gene suggests that other domestic species may have a similar trait that could be used to great advantage. Procedures to select for prolificacy are now being developed.

Booroola, a prolific strain of sheep raised in Australia. Prolificacy in the Booroola appears to be controlled by a single gene, a finding which suggests other domestic species may have a similar trait.

Second, embryos of the prolific Booroola were transferred into Coopworth ewes (from New Zealand) for quarantine in Hawaii before being brought to the U.S. mainland. The imaginative method for importing the Booroola could be adopted for importing superior genetic material in other species while at the same time protecting the health of American breeding herds.

Exchange of technology and breeding stock through academic and industrial channels will become increasingly important in the future if the United States is to retain its leadership in several phases of animal agriculture. Feed companies, pharmaceutical companies, and others have opened offices overseas primarily to supply foreign markets and also for their own development. Similarly, American land-grant institutions depend in part on international contacts through selected institutions.

As representatives of the Illinois agricultural community, members of the College of Agriculture must establish professional working relationships with fellow agriculturalists overseas. This rapport can be achieved by exchanging visits, attending workshops and conferences, writing letters, and educating our own and international students in the agricultural sciences.

Cooperation can also be fostered by developing formal and informal ties through the International Soybean Program (INTSOY), the Consortium of International Crop Protection (CICP), and similar programs. Yet another way of promoting scientific exchange might be to encourage young agricultural scientists to undertake sabbatical studies in other parts of the world. The cross-cultural experiences thus gained can be valuable when we interact with Illinois farmers, students, and scientists.

James B. Sinclair, professor of plant pathology; Leif H. Thompson, associate professor of animal science

Women in Agricultural Development

Jean M. Due and Jean Treloggen Peterson

Scientists who plan and implement international agricultural development programs have to know something about the cultures with which they work. Recently some scientists have become particularly interested in the role of women in economic development. If women are an important part of the labor force but are confined to specific roles in agriculture or commerce, a development project that does not consider them can progress very differently than expected.

To most westerners, the following scene from Zimbabwe would be a lesson in cultural differences. A family is trying to catch an airport bus. The husband is running toward the bus, carrying a light briefcase and his wife's purse. Behind him is his teenage son carrying a small sports bag, and behind the son is his mother, running as hard as she can with a baby on her back and baby supplies in both hands. Behind her, also running at top speed, is the teenage daughter balancing a huge suitcase on her head. (All succeed in catching the bus.)

Development planners working with this family would have to fully understand the roles played by each member. They would have to know that the husband controls the money and the women do half the agricultural work. They might also need to know how mutually satisfactory this arrangement is, how money is managed, and how various decisions are made.

Women's roles in farming. Ignorance of sex roles in other cultures can lead to costly mistakes and failures. In the mid-1960s, for example, the Taiwanese introduced a high yielding variety of swampland rice into West Africa. They trained the men to plant the rice and paid them during the training period. After the Taiwan team left, however, little of the new rice was planted, for the simple reason that it is the women who do most of the rice growing, not the men. Understandably, the men dropped the new technology as soon as their wages ended.

To avoid failures such as this, researchers are currently studying women's roles in the farming systems of Tanzania. Crop scientists there are developing new higher yielding, drought- and disease-resistant varieties of beans (*Phaseolus vulgaris*). When these varieties are introduced, it will be important to know who decides which crops are planted, who chooses the bean seeds, and who undertakes various tasks. Only then can the new varieties be given to the appropriate persons.

Illinois researchers have found that in more than half the cases in Tanzania the husband and wife together decide which crops are planted. Exactly which seeds are planted, however, is decided primarily by the women and children. Extension personnel are currently men and relate almost exclusively to male farmers; obviously, some women must be hired so that both women and men will receive the necessary information.

In addition to making certain key decisions, women provide at least half the agricultural labor in tropical Africa (with variations by region and religion). A glance down the "total" column in the table gives a general idea of their share of different tasks in Tanzania. For bean scientists, it will be important to know that women do 59 percent of the work involved in bean growing.

The relatively minor role of women in marketing may provide another reason that some new projects fail. For example, if the beans just discussed are introduced, they will require more weeding and harvesting. Since these are traditionally female tasks, the women will have to work harder. The men, who traditionally do the marketing, will have more income and are likely to pocket the surplus. The women will clearly be working harder for less and may eventually refuse to do so. The project would then fail.

It has perhaps not always been fully appreciated that when the work load of women is increased, so is their need for labor-saving devices. In Zambia, women put in more hours a day farming than their spouses (8.5 compared with 7.4) and an additional 4 hours doing household chores and child rearing. They contribute 53 percent of the agricultural labor (and therefore income), and they also earn more income than men do from brewing and selling beer, weeding for their neighbors, selling small amounts of vegetables, and doing other chores. In all, women earn 54 percent of the family income.

Not surprisingly, women in Zambia want labor-saving devices to help them in farming. They also want access to credit, clinics, and wells; credit is now available to women in their own names only if they are widowed or divorced. Finally, they need more labor-saving devices for the home. If these needs are not met, the new technology could simply create more hardships for Zambian women.

New technology, therefore — like anything new — does not always promote everyone's well-being.

Percentage of Labor Days per Acre Contributed by Females in Sampled Families, Kilosa, Tanzania, 1980

Task	Maize	Sorghum	Rice	Cotton	Beans	Sunflower	Total
				percent			
Land preparation	44	37	61	39	55	34	46
Planting	52	41	77	48	60	40	55
Weeding/thinning	51	43	65	51	59	40	52
Spraying	0	0	0	0	0	0	0
Harvesting	54	46	71	51	69	43	58
Marketing	17	16	50	31	0	12	21
	48	40	67	39	59	39	48

Women in Zambia traditionally grind cereals, the major food staples, with mortar and pestle. This kind of hard, time-consuming work could be lessened with the help of labor-saving devices.

Esther Boserup argues that a single technological change in farming can entail a "radical shift in sex roles in agriculture." In areas where old methods of cultivation have been replaced by plow cultivation, men have taken over the plowing, and men rather than women now operate the main farming equipment. If men also receive credit, new seed varieties, and tools to increase their productivity, the gap between the productivity — and income — of men and women widens. The men then "represent modern farming in the village, women represent the old drudgery." (Esther Boserup, *Woman's Role in Economic Development*. St. Martin's Press: New York, 1970, p. 56).

Family dynamics. Negative consequences such as these can be avoided with more awareness of everyone's needs and some attempt to anticipate changing needs. At the same time, we cannot predict that cultural change will always create a hardship for women. In many situations, people do not make gender discriminations but simply use human resources the best way they can. This fact has been documented by research on sex-role complementarity, or how both male and female roles change in relation to each other. Benguet Province in the Philippines is an interesting example of this point.

When the United States took over the Philippine Islands, a concerted effort was made to enroll every child in school. Because agriculture in Benguet depended on female labor, however, parents often tried to keep girls from being enrolled. When recalling their childhood, men remember days of play, some hunting or

Indian women sorting soybean seeds. Women's roles in the farming systems of developing nations are being studied to ensure that women, not just the men, receive appropriate extension information.

Harvesting in India. In many developing nations, weeding and harvesting are tasks traditionally performed by women, a fact that scientists must take into account when planning economic development programs.

trapping of pigeons, and some responsibility for the family hog. Women recall long days digging yams in the fields and carrying the heavy loads home. These families were ensuring their subsistence through female labor.

The agricultural change that occurred later in the century led to a shift in these roles. After World War II, foreigners introduced intensive commercial vegetable cultivation to the area. Influenced by their own culture, they introduced the technology to men, thus promoting a dramatic increase in male participation in agricultural labor. This more intensive cultivation is heavily dependent on credit, and men have better access to credit than do women.

When the males became more involved in horticulture, the females began to go to school. The jobs they had access to because of their education became an important way of offsetting the high risk of vegetable farming, and now women outnumber men three to one in colleges and universities in the area. While female children are channeled into higher education, male children are more likely to be discouraged or drop out because their labor is needed on the farm.

Complementarity plays itself out in the course of individual family histories. It usually involves strategies that extend beyond the nuclear family and entails lifetime cooperation among siblings. Extended families help one another with labor, child care, children's education, credit, and the like as needs change. This flexibility ensures a society's continued existence in the face of rapid change.

The Philippine example shows that change cannot always be predicted: rather than one segment of society suffering, roles may simply change. Sex-role complementarity can be expected to vary across cultures, and much more research is needed to help scientists apply their techniques with wisdom. A current study in the Caribbean will provide an interesting comparison with the Philippine study.

Research on women in developing countries grew from the Percy Amendment of 1974, which mandates that scientists give attention to women in any federally supported development effort. Focus on women — often referred to as "Women in International Development," or WID — is now a part of international research on every major land-grant campus. It has contributed materially to the success of development efforts, and it has also helped make courses more relevant for foreign students studying in the United States and for U.S. students with international career interests.

Jean M. Due, professor of agricultural economics, has been involved in research in Tanzania and Zambia. Jean Treloggen Peterson, associate professor of family relationships, has conducted research in the Philippines.

Views

Agriculture in the Third World

Norman E. Borlaug

Picture the annual world harvest of cereal grains as a "highway of grain" circling the earth at the equator. This imaginary highway would be 65 feet wide, 8 feet deep, and a little over 25,000 miles long. The world's people consumed this entire amount of grain last year. This year the highway of grain must be reproduced in its entirety and another 650 miles added to its length just to feed the growing world population at the same, and often inadequate, level. More than half of this food and 80 percent of the additional food requirements each year will be consumed in the less developed countries of Asia, Africa, and Latin America, where more than 3.5 billion of the world's 4.7 billion people live.

World food production of all types is today about 4 billion metric tons, representing about 2 billion tons of edible dry matter. Of this total, 99 percent is produced on the land; only slightly more than one percent comes from the oceans and inland waters. Plant products constitute 93 percent of the human diet, with about thirty crop species supplying most of the world's calories and protein. These include eight species of cereals, which collectively supply 52 percent of the total world food supply.

Until the mid-1960s, very little agricultural research was being conducted in most of the developing world on the major food crops. The network of international agricultural research centers, established over the past two decades to work on the major food crops and farming systems of the developing world, has been important in stimulating agricultural research in the Third World. The improved varieties and production practices developed by scientists

Norman E. Borlaug, who has been called the father of the green revolution, was awarded the Nobel Peace Prize in 1970 for his work in developing high-yielding varieties of wheat.

Science Year photo by Ted Streshinsky, © 1983 World Book, Inc. By permission of World Book, Inc.

In his research with wheat varieties, Borlaug has worked with short-stemmed triticale (center), which has a bigger head than its two parents, rye (left) and wheat (right).

Science Year photo by Ted Streshinsky, © 1983 World Book, Inc. By permission of World Book, Inc

at the International Maize and Wheat Improvement Center (CIMMYT) in Mexico and the International Rice Research Institute (IRRI) in the Philippines, in conjunction with researchers in developing countries, did much to avert the spectre of famine for millions of people in the 1960s and 1970s.

The green revolution. The introduction of high yielding wheat and rice varieties, in combination with other improved agronomic practices (especially fertilizer) that permitted these varieties to express their high genetic yield potential, has had a major impact on transforming food production in Asia, the world's most populous continent. Although larger farmers in favorable production environments were the first to benefit from green revolution technologies, they were soon followed by smaller farmers.

Today, both large and small Asian farmers are harvesting nearly twice as much wheat and rice — 250 million extra tons annually — as they did two decades ago. Coined the green revolution, this transformation has few parallels in the history of agriculture, other than perhaps the spread of hybrid corn in the United States during the 1940s and 1950s.

New green revolutions needed. Despite the tremendous food production successes achieved in Asia, the Middle East, and parts of Latin America in recent years, agriculturalists today face even greater production challenges to feed future generations. New green revolutions must occur in the more marginal production areas of Asia, Sub-Sahara Africa, and parts of Latin America. Such areas are generally rain-fed environments with difficult production conditions such as moisture and temperature stresses, soil fertility problems, and diseases and pests.

Some lessons learned. How can we help ensure that these new green revolutions in food production will indeed occur? In reflecting on my forty years of personal experience in attempting to assist developing nations improve the productivity of their agriculture, I have learned certain lessons that bear directly on the challenge ahead:

1. Despite the fact that 50 to 80 percent of the total population in the Third World directly engages in agriculture and animal husbandry, the agricultural sector in virtually all developing nations is the economic "ugly duckling" that is exploited for the benefit of the minority in the urban sector. Relatively low priority is given to investments in crop research, water resource development, rural roads, input delivery systems (for seed, fertilizers, pesticides), credit, and grain storage facilities.

This "exploit-the-agricultural-sector" political tilt is also manifested in cheap-food policies sponsored by many governments of developing nations in order to keep food prices low and, consequently, the better-organized urban sectors quiet. Too often, these policies are reinforced by easy-term food aid and surplus disposal programs sponsored by food-exporting nations. Such policies have time and again retarded agricultural development in food-deficit, developing nations. Obviously, food aid is another matter in times of emergencies caused by natural disasters such as droughts, floods, frosts, and disease epidemics.

2. A low-yield, stagnant, traditional agriculture cannot be transformed into a high-yield, productive agriculture without the development and widespread application of a package of improved technology. An aggressive, interdisciplinary research effort is essential for developing such packages. The new technological practices must have the potential, when properly applied, of increasing yields

Borlaug, pictured here at CIMMYT, the International Maize and Wheat Improvement Center in Mexico. An important part of Borlaug's work focuses on teaching young scientists his techniques. He is also a strong advocate of transferring research findings to farmers through extension activities.
Science Year photo by Ted Streshinsky, © 1983 World Book, Inc. By permission of World Book, Inc.

on farmers' fields by at least 50 percent (often yields can be increased several fold) over that of the traditional methods. Moreover, this increased yield must be achievable within acceptable levels of risk for the farmer. Appropriate economic policies are also essential in stimulating the farmer to shift to improved technologies.

3. Effective research programs, capable of developing useful methods and materials for revolutionizing crop production, require continuity both of scientific personnel and program objectives. Generally it takes a minimum of six to eight years of creative, dedicated, and adequately supported research work in various disciplines to produce the information and improved varieties from which a package of improved production practices can be formulated.

The refinement and transfer of appropriate production technologies requires the skill of agricultural scientists — integrators — who are also interested in increasing agricultural production to serve human needs. Once developed, the production package must be tested on many farms and modified as necessary to reduce farmers' risk as much as possible.

Research integrators must also be able to anticipate and sense when political leaders are willing — often because of serious, pending food shortages — to make important changes in agricultural development strategies. Often at such moments a scientist can best convince national leaders to put into place the three economic pieces of the jig-saw puzzle, namely, the availability at reasonable prices of the necessary production inputs (especially fertilizers), credit for the small farmer before the sowing season, and adequate output prices at harvest that are announced before the planting season. With these pieces in place, an aggressive, well-publicized national production campaign can be launched with support from the agricultural extension service staff.

4. Agricultural extension programs in developing nations have often been accused of not transferring improved technology from experiment stations to farms, thereby contributing to the perpetuation of low yields and in turn to worsening food shortages. In most cases, the so-called new technology emerging from experiment stations has been economically nonviable, incapable of increasing yields adequately within acceptable levels of risk to the farmer. The result is agricultural stagnation and, in fact, often a reduction in per capita food production.

Clearly, the development of an agricultural extension service that is not closely linked to a dynamic research system has little to offer farmers in the way of improved technology. With the development of national research and production systems, however, I am confident that agricultural extension systems in developing countries can become more effective in the years ahead. Also encouraging is the growing trend for at least part of the technology to be generated on the fields of farmers who are representative of those for whom the technology is being developed.

What the United States can do. The United States can and must play a critical role in solving the food-poverty dilemma in the Third World. First, as the largest food exporter, the United States will continue to serve as the world's breadbasket. While there is an oversupply in the international grain markets today, U.S. farmers face long-term prospects of considerably greater world demand for their agricultural products. Second, the United States has done more than any other country to transform its agriculture into a dynamic, highly efficient production system. Through scientific institutions like the University of Illinois and our foreign aid program, we have an even larger role to play in future years to help assure the agricultural development of the poor, food-deficit nations of the world.

The lack of continuity in many U.S. technical assistance programs has seriously affected the payoffs from past efforts. One of the main reasons is that the turnover of expatriate scientific staff is too rapid. Assignments of two to three years are of little value to the host country. It takes a minimum of three to five years for visiting scientists to familiarize themselves with the order of importance of the agricultural problems, language, and culture of a new country and to contribute productively to agricultural development.

The motivation for U.S. technical assistance has self-interest as well as humanitarian elements to it. In this increasingly interdependent world, no country, however rich and abundant in resources, can exist as an island unto itself. International trade is essential today to the economic well-being of every nation; history has proven that chronically food-deficit, low-income countries don't make dynamic trading partners.

Further, peace on earth will never be achieved as long as a fourth to a third of mankind lacks the basics of life: adequate diets, shelter, health care, education, and employment opportunities. As we should know by now, overpopulation, poverty, and hunger are the breeding grounds for revolution.

Cautious optimism. In summary, I believe that, if proper emphasis is given to agriculture and if sound financial policies are established and implemented, the line can be held on the food production front during the time of the next doubling of the world population. If this is to be achieved, it will require far fewer words and sensationalized reports and much more research action and production. Moreover, it must be remembered that producing more food and fiber and protecting the environment can, at best, be only a holding operation while the "population monster" is being tamed.

The attitudes of scientists, political leaders, and the general public will be decisive in determining whether we reach — or fail to reach — the food production targets needed to sustain world civilization. If we fail in this endeavor, it will only prove the irrelevance and folly of whatever feats we accomplish in all other walks of life.

Norman E. Borlaug, consultant, International Maize and Wheat Improvement Center (CIMMYT), Londres 40, Mexico City, Mexico 06600

Hay production

The market for Illinois hay is picking up. Although legume hay is not as easy to market as corn and soybeans, it has its good points, says Don Graffis, extension specialist in forage crops. First of all, the demand from the dairy industry in the St. Louis milkshed and in northwestern Illinois is reliable. Horse farms, race tracks, and zoos are other dependable markets, along with similar uses in states where high quality hay is difficult to produce. Reasonable profits can be expected from all of these markets.

Second, Illinois farmers see legume hay as an excellent way to control soil erosion. Since they have to reduce soil loss to the tolerable limit by the year 2000, they figure they might as well turn a profit while they're at it.

Because of its bulkiness, though, hay is expensive to ship. Nothing but hay of the highest quality is worth the trouble, Graffis says. Illinois has therefore embarked on a Quality Hay Program, which has several objectives: to encourage farmers to produce high quality hay, to improve the marketing of hay, to upgrade feeding and production efficiency in the livestock industry, and to plant hay on more acres of erosion-prone land in the state.

Analysis of hay for feed nutrients is very important, Graffis says, if farmers are to market the crop to their advantage. During the last ten years, the Near Infrared Reflectance Spectroscopy (NIR) procedure for analyzing hay has been developed and has proved to be both rapid and accurate. Producing results comparable to the more expensive, standard wet chemistry methods, NIR has now been approved for hay analysis.

Honey bees and mites

A small, exotic, parasitic mite is threatening the beekeeping industry in the United States. Feeding on the host's blood, the mite lives in the tracheae (breathing tubes) of the adult honey bee. The damaged walls of the tracheae affect the bee's ability to fly and significantly shorten its life span. A colony that has a 30 percent infection rate will not survive the winter in the temperate zone, says Gene Killion, extension specialist in beekeeping.

Acarapis woodi (Rennie), as the mite is called, lived for years in Europe and later in South America. The mite was not considered a threat to bees in this country, because the U.S. Honey Bee Act regulates the importation of bees and semen. In 1984, however, the mite was found in an apiary in Weslaco, Texas, in the Rio Grande valley. Since then the mite has been confirmed in seven states.

Although Illinois is still free of the problem, a mite-detection workshop was recently conducted to train participants in the procedures used to examine honey bees for the mite. The workshop was part of a collaborative effort of the University of Illinois, the U.S. Department of Agriculture, and the Illinois Department of Agriculture.

The University and the Illinois Department of Agriculture have also established a small diagnostic laboratory for mite detection. Preparedness is the watchword, Killion says, since honey bees provide a valuable pollination service to Illinois agriculture.

Examining samples of honey bees for mites. A section of the thorax is removed and placed in a solution of potassium hydroxide, which leaves the trachea exposed after incubation for 24 hours. If the mite is present, it can be seen under a microscope. Inset: the mite, *Acarapis woodi* (Rennie), 1,000x.

Farming Systems

Farmers who are facing difficulties on the rolling, erosion-prone land of southern and western Illinois may get some help before long. The Illinois Agricultural Experiment Station is developing a systems approach to help solve agricultural problems in these regions. Administrators and faculty members in the College of Agriculture are now reviewing a proposal that will eventually be used to solicit funds from private and public sources.

The effort was prompted by the economic plight of many farmers, general economic conditions, and the need for soil conservation. Environmental issues, questions about the best technology to use, and concern that sustainable agricultural systems be found also enter the picture. A sense of urgency surrounds the proposed project because of the economic situation.

The College of Agriculture is prepared to expand and coordinate its research and educational efforts to meet the challenge. Central to the proposal is the participation of many other units, among them, the Natural History Survey, the State Water Survey, agricultural and research centers in target areas, and other universities.

A close working relationship will be established among researchers, farmers, extension people, and leaders in agribusiness and the community. This proposed project management committee will ensure that the problems critical to farmers, their families, and their communities are clearly identified and dealt with effectively.

The computer will be an important tool in the farming systems project. A computer network will link farmers, agribusiness, and county extension offices in selected test regions. Among other things, the proposed computer system can provide small- and medium-sized farms with management aids such as timely price, market, weather, and other information used by very large farm operations and agribusinesses.

A hydroponic greenhouse where lettuce is grown. In a hydroponic system the plants are grown in a liquid medium that provides nutrients as needed. The temperature of the roots and the air in the growth room are controlled.

Kitchen factories

Production of vegetables in so-called kitchen factories has captured the imagination of some and elicited derision from others. But whether economic success or failure awaits them, kitchen factories can teach us much about how to produce plants in a controlled environment, according to John Gerber, associate professor of horticulture.

Nearly all of a plant's needs can be manipulated in a specially designed setting. The producer can supply artificial lighting, a hydroponic system for feeding and watering the plants, and controlled temperatures in the growth room. Still not economically realistic because of the high cost of lighting, controlled systems nevertheless make an excellent research tool for studying plant requirements.

The Archer Daniels Midland Hydrofarm in Decatur, Illinois, stands midway between a traditional greenhouse system and a completely controlled system. Strongly in the ADM system's favor is that it uses waste heat and carbon dioxide from a nearby alcohol distillation factory to heat the greenhouse where lettuce is grown.

With a hydroponic feeding and watering system, nutrients are available as needed and the temperature of the root system is controlled. The environment can be adjusted to take advantage of the available light. Research at ADM and in the Department of Horticulture at the University of Illinois is aimed at finding the best nutrient solutions and the optimum temperatures for the solutions and the air in order to grow lettuce and other crops.

The high cost of shipping vegetables from the South and West lends appeal to the idea of local food factories. But first we must cut down on the cost of heat and labor, Gerber says. Using heat from power plants or heat-producing industries should take care of the first of these problems. And using automation with computer controllers should take care of the second.

Research in Holland has already suggested ways that mechanical harvesters can be used in hydroponic growing systems to reduce labor costs. The economic feasibility of kitchen factories remains to be seen, but controlled-environment agriculture is within the realm of possibility.

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Letters continued from page 2

Would like to see more information presented on pesticides, crop production, and Illinois pest problems.

Washington, D.C.

Need more vegetable and fruit research reported.

Scheller, Illinois

I would like a way to obtain reprints of journal articles by authors in your publication.

Amherst, Massachusetts

We no longer pull reprints because of the expense, but authors will supply photocopies of their articles upon request. Mail requests to this office (see address in box below) and I will forward them to the authors. Readers are also welcome to make their own photocopies from the magazine. — Editor

How about more information for the small farm family and suburbia? After all, the Land Grant Act was to help the poor farmer's sons and the blacksmith's sons. How best can I improve the operation on my 10-acre farm?

Lafayette, Indiana

I am sure the Agricultral Experiment Station must have a number of other publications (at charge). . . . These might be listed for sale in each issue of *Illinois Research*. I for one might be interested in purchasing copies of surveys, reports, investigations on agricultural research topics.

Westhaven, Illinois

Yes, we do have many publications, some free and some for sale at low cost. Please write to the address in the box below and ask for our catalogue. As space and time permit, I include the names of publications that are related to the theme of an issue. However, some research is so new that few publications are available for the nonspecialist reader. — Editor

My disappointment in this publication is the absence of any information on bees. . . . Who could I contact about this? I am sure you print booklets or reports on bees. They serve a very useful place in the ecology of our plant life.

Carterville, Illinois

This office does publish some materials on bees. Please write to the address in the box below and ask for our catalogue. — Editor

Address communications to Editor, Illinois Research, University of Illinois at Urbana-Champaign, 47 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801.

Please limit letters to 250 words.

Renewal notice

Many subscribers still have not responded to the renewal notice that was incorporated in a special wraparound cover on the spring/summer 1984 issue of *Illinois Research*. To avoid being dropped from the mailing list, please return the renewal form no later than May 15.

If you've misplaced the form, a postcard will do, but be sure to include all of the information from the mailing label. For a change of address, copy down all of the old information as well as any changes.

Readers who were not sent a renewal notice will automatically continue to receive *Illinois Research*.

Illinois Research

Spring 1985

Illinois Research

You should see the place down the road!

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 27, Number 2

The Cover

The facilities for housing laboratory animals and the farm animals used in production research must satisfy two major conditions. First, the facility must safeguard the health of the animals. Second, the housing and care given the animals must be suited to the purpose of the research. If these conditions are not met, the findings may be biased. Thus, animals serving as models in biomedical research must be housed in a controlled environment, and those used in production research must be kept under simulated farm conditions.

"At a time unlike any in the past, we must envision the future."

Illinois Research

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Animal Research

1985 - Directions - 1995

Animals Serving Humanity

During the Neolithic Age, some 10,000 to 20,000 years ago, *Homo sapiens* learned to turn herds of wild animals to prevent them from roaming too far from the tribe and to guide them to better pastures. With their newfound companion, the domesticated dog, our early ancestors took the first steps in the transition from hunter to herder. Later they tamed cattle, sheep, and goats, protected them from predators, and provided them with shelter and food during the winter. When humanity arrived at the dawn of civilization 5,000 years later, domestic animals provided a continuing source of food, clothing, labor, and companionship.

As the centuries passed, the bond between humans and animals strengthened. Animals were selected for special traits, and breeds were developed to enhance their usefulness. Thus, breeds of dogs were produced for herding or hunting or companionship, cattle were selected for meat or milk production, strains of sheep were developed mainly for the production of wool or mutton, and swine were raised for bacon, lard, or — in recent times — lean meat.

In the modern era of animal agriculture, people have learned to use modern techniques in feeding, breeding, and physiology to raise animals to new levels of productivity and utility. Modern management practices have been developed to provide balanced diets and comfortable surroundings. Advances in veterinary medicine have rendered our herds and flocks remarkably free of disease. Animal scientists have made many of the basic discoveries in the biomedical sciences; these discoveries in turn have been widely used in human and animal medicine.

Basic scientific findings have also helped improve the efficiency with which animals produce food. More than half of the nutrients, two-thirds of the protein, and four-fifths of the calcium in the American diet are derived from poultry and livestock. Furthermore, the nutrients in foods from animal sources are of a higher quality than those in the plants consumed by animals.

Modern animal agriculture is involved with more than animal production. It is also concerned with the well-being of animals, their responses to their surroundings, and their interactions with nature and their human stewards. This issue of *Illinois Research* addresses several areas of interest in the study of animals in the service of humanity.

W. R. Gomes, professor and head, Department of Dairy Science

Animal Behavior and Productivity

Harold W. Gonyou

How do newborn piglets find their way to the sow's teats? Is there an easy way to trick a ewe into accepting a strange lamb? Do mean cows produce mean calves? These and many other facets of animal behavior are being studied here in the College of Agriculture and at several other agricultural institutions. The research does not arise from mere idle curiosity.

Almost by definition, animal agriculture involves interaction among sentient species. Animals are complex creatures that have more traits in common with humans than with other living organisms such as plants. This same complexity enables individual animals to adapt to their environment through actions characteristic of their species.

Behavior — the response of an individual or group to its environment — is now recognized as an important component of successful animal production. The study of animal behavior is therefore an appropriate field for basic and applied research. Work in this field can benefit humans by helping us augment current production or reduce problems that act as a check on productivity. For example, we can increase the maximum growth rate of feedlot cattle or reduce post-weaning stress and weight loss in piglets.

Of course these benefits don't result from behavioral changes alone; other disciplines contribute to the improvement as well. Some problems are essentially behavioral, however. Aggression in pigs, mismothering in sheep, cannibalism in poultry, and the buller-steer syndrome (excessive mounting) in cattle are all behaviors that should be eliminated or at least reduced to acceptable levels.

Behavioral research in animal production can also be applied to questions of animal welfare. As the keepers of domestic animals, we are ethically obliged to care humanely for these relatively high forms of life. In addition to behaviors that indicate distress, animals have behavioral needs that should be accommodated in our production systems. To address questions of productivity, problem behaviors, and welfare, we must first understand the principles of animal behavior.

Learning theory. Historically, research in animal behavior has been divided into two schools: learning theory and ethology. Learning theory, the more familiar of these two schools in North America, has been pursued primarily by researchers in psychology. An important principle coming out of this work is that, through learning based on previous experiences, an animal can improve its behavior. For example, a newborn pig wanders around its mother for some time until it finally locates a teat. Having suckled once, however, the piglet can quickly return to the teat a second time. With experience, bulls improve their mating behavior, thus reducing the number of incorrect mounts.

The extent of an animal's ability to learn must be taken into account in designing equipment. In nipple watering systems, for instance, an animal has to be able to learn that it can obtain water from a nipple. At first, pigs do so only out of curiosity, but after finding they can get water this way, the nipple becomes associated with drinking.

Animals can learn to manipulate their environment in other ways as

well. Chickens have learned to control the lighting in their houses, and dairy cows have been given the opportunity to adjust their milking machines. Pigs quickly learn to adjust the temperature in their houses by pushing specially designed heater controls. In a most interesting use of learning, sheep have been trained to open gates for leading other sheep to slaughter. Just before reaching the killing pen, the leader exits through a special gate and returns to move another group.

Not all learning benefits agriculture, however. Rats and other pests learn to avoid poisonous baits, thus thwarting control tactics. But even aversive conditioning, as it is called, is now being investigated for its positive uses. Under certain conditions, preying on lambs can be discouraged by treating predator baits and lamb carcasses with a compound that produces nausea. Associating the nausea with the meat, coyotes will avoid lambs thereafter. Similar experiments are being performed to discourage birds from eating vegetable and fruit crops.

A ewe can be encouraged to foster a strange lamb by dressing it in a cloth jacket that contains birth fluids or odors from her own lamb.

Ethology. The other school of behavior is ethology. Developed primarily in Europe, the principles of this discipline emphasize the interaction of animals with their natural environment. For survival, an animal needs an innate or easily learned repertoire of behaviors suited to its surroundings. Many of these behaviors are related to interactions with other members of the same species. Thus, another principle states that each species has unique genetic and physiological mechanisms for producing behavior that is normally favorable to the animal.

The ability of a newborn animal to locate a teat and elicit care from its mother is a good example of a behavior essential to survival. Shortly after birth, calves are able to stand and to begin seeking a teat. During the search, the calf is usually attracted to overhanging objects and angles, which stimulate the calf to push and probe with its head. The cow helps out by putting herself in a convenient position so that the calf can contact the cow's underline quickly. The calf then locates the udder and finally a teat for its first suckle. Within hours after giving birth, cows, sheep, and goats form a very strong bond with their own offspring and won't allow others to suckle.

Nursing is important in all mammals because it is the primary way that the young are nourished. In pigs, an elaborate system of sow grunts and piglet responses leads up to a 15- to 20-second release of milk about once an hour. By the time the milk becomes available, fighting among the piglets has stopped, each one has settled onto its own particular teat, and the littermates are ready to eat. Recorded sow grunts, used in artificial feeding systems, may eventually provide a way to control feeding behavior.

Most of our domestic species normally live in large social groups. To maintain order, animals must establish a dominance hierarchy. When a new group of pigs is formed by merging other groups, the pigs fight for several hours, and it may even be days before a stable hierarchy is formed. If the feed of any group such as gestating females is limited, the group members will compete for it. Unless appropriate management practices are used, some of the animals will get much less than their share.

But even in well-fed groups, problems related to social interactions occur. For example, the buller-steer syndrome in cattle is particularly troublesome in groups of more than a hundred individuals. Producers could benefit from information on the relationships among animals in large commercial herds.

To mate and reproduce successfully, animals must engage in appropriate sexual behavior. Among other things, they have to attract the opposite sex during periods of sexual receptivity. Rams produce chemical substances called pheromones, which attract estrous ewes; boars attract sows in a similar way. The odor of pheromones has no effect on nonreceptive females.

Species differ in their sexual strategies. For example, sexually receptive cows give visual cues such as mounting other cows in the herd. Understanding this sort of behavior is necessary in facilitating artificial insemination.

Animal welfare. Ethologists hypothesize that the behaviors necessary for survival in a natural environment may be driven by internal needs rather than by external stimuli. If the supposition is correct, the behaviors would persist even if the environment were to change drastically.

This idea underlies the complex issues related to animal welfare. If animals do in fact have behavioral needs in addition to the need for food and protection from the elements, then managers must consider them. Failure to allow animals to ex-

Nipple-waterers provide a continuous supply of fresh water. This method takes advantage of a farm animal's ability to learn how to operate the device.

press innate behaviors or to provide satisfactory substitutes could result in inner conflict leading to psychological and possibly physiological stress.

A number of questions are currently being raised. For example, must sows and horses be given fibrous feeds to satisfy what may be a need to chew? Should pail-fed calves, which often suck the ears of pen mates, be given nipple feedings to relieve a need to suckle? Do animals express other, as yet unrecognized needs in aggression and problem behaviors or through poor productivity? Unfortunately, the answers to these questions are not simple, so we are continuing to develop theories and test them as research progresses.

Other disciplines. The study of animal behavior does not stop with the classical views of psychology and ethology. Behaviorists also work at the molecular level with transmitter substances and hormones on up to the level of animal populations in which game theory is applied to behavioral strategies. In our research we draw upon physiology, genetics, nutrition, and ecology. The study of animal behavior is a diverse and growing discipline that is gradually taking its place in animal production.

Harold W. Gonyou, assistant professor of animal science (behavior)

Tips on Handling Livestock

Temple Grandin

There's a trick to designing a good livestock-handling facility: the designer has to work with the natural behavior patterns of cattle, not against them. At odd moments the designer may even have to think like a cow. As an offshoot of research on livestock behavior, the design of handling facilities is improving on farms, in feedlots, and at slaughter plants. When loading ramps, chutes, and corrals are designed with particular behaviors in mind, we see less stress, fewer bruises, and a drop in the amount of handling needed.

Unlike the conventional straight chute, a curved one is more efficient for moving cattle along because they cannot see the truck or the squeeze chute until part way up the chute. A curved chute also takes advantage of the animal's tendency to circle around the handler, who works along the inner radius of the chute (Fig. 1).

Circling is a natural behavior in cattle. They will turn and face someone moving through their pen and will circle around the person, while remaining at a safe distance. The size of the flight zone depends on the tameness of the animal (Fig. 2). Completely tame cattle will let people touch them. Feedlot and pastured cattle in Illinois usually have a flight zone of 5 to 20 feet (2 to 6.5 m).

The best place for the handler to work is on the edge of the flight

Fig. 1. A curved chute with high solid sides is more efficient than a straight one. The handler works along the inner radius of the chute, thus taking advantage of the animal's natural circling behavior.*

zone. Penetrating it makes the animals move away, and backing out of it makes them stop moving. If an animal rears up in a chute or tries to turn back when being driven down an alley, the handler should back up and leave the inside of the flight zone.

Having wider peripheral vision than humans, cattle can readily see people and objects moving outside a chute fence constructed of bars. Easily distracted, the cattle tend to balk. Distractions can be virtually eliminated by using solid fences on loading ramps and the chutes leading up to squeeze chutes, which are used for veterinary procedures. A curved chute with solid sides at a meat-packing plant is pictured in Figure 3.

The animals should be able to see only straight ahead in the single-file chute. Since they will refuse to approach a dead end, however, the sliding gates in the chute should not be solid (Fig. 4). When cattle can see other animals walking up the chute ahead of them, they tend to follow the leader.

Cattle are sensitive to strong contrasts of light and dark and to differences in floor texture. They will often refuse to cross a shadow or a drain grate. Lighting in a livestock-handling facility should therefore be even and diffuse, and harsh contrasts of light and dark should be minimized. Livestock also tend to move from a darker into a brighter area, provided the light is not directed into their eyes. Lamps can be set up to illuminate truck interiors and chute entrances to encourage animals to enter, especially at night. Loading ramps should not face into the sun because the blinding light causes cattle to balk.

The job of handling livestock can be eased considerably once we understand their natural behavior patterns. In the long run, handling facilities designed to take these patterns into account work to the handler's advantage and relieve some of the animals' stress.

Temple Grandin, graduate student in animal science and behavioral studies. The author has a consulting practice for designing livestock-handling facilities.

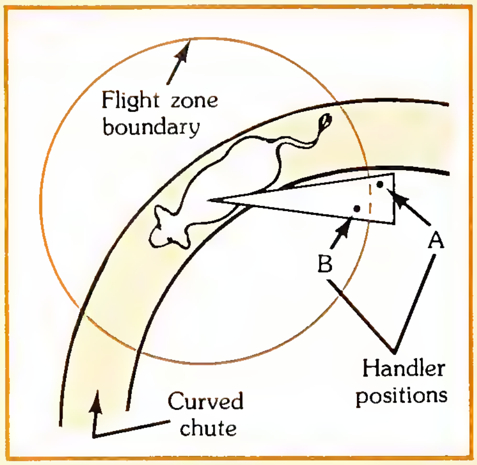


Fig. 2. The best place for the handler to stand is on the flight zone boundary, off to one side of the cow's rear end and outside the blind spot. The handler penetrates the flight zone to position B to move the animal, and retreats to position A to make the animal stop.

Fig. 3. In packing plants, the use of a curved chute with high solid sides helps reduce animal stress and labor requirements.*

Fig. 4. The sides of the single-file chute should be solid, but the sliding gates should be constructed of bars. This design encourages cattle to follow each other.*

* *Livestock-handling facility designed and photographed by Temple Grandin.*

Equine Research

Gordon J. Baker

Ranking fourth in the nation, the Illinois equine industry has some 273,000 horses conservatively valued at more than $400 million. The importance of the industry is reflected in strong research programs in the College of Agriculture and the College of Veterinary Medicine. A few of the many important research projects under way include studies of the physiology of horses during exercise, illness and death of foals, inflammatory diseases of joints and bones, and Potomac horse fever.

In recent years, equine exercise physiology has become a focus of interest here and elsewhere (Fig. 1). To measure coronary vasodilator reserve — or the capacity of the heart muscle to expand — trained ponies were tested at rest and during maximal exercise on a treadmill.

When the exercising ponies were given adenosine, a drug that increases the heart rate, the coronary vasodilator reserve was adequate for top performance. Similarly, the flow of blood to the heart increased sufficiently to meet the greater demand for oxygen during exercise with no reduction in blood supplied to the heart muscle. Unless the equine athlete has overt heart disease, cardiac output and reserve should be adequate for maximal exercise.

The serious illness or death of many foals is a continuing problem in spite of vaccination programs and improved management practices. Currently the Horse Racing Program of the Illinois Department of Agriculture is funding research projects to study the causes of foal loss. One major study is concerned with pneumonia. During the 1984 foaling season, data on the incidence of the illness and other relevant information were collected with the cooperation of owners, breeders, and veterinarians. Once the data are analyzed, appropriate management practices will be recommended.

In other work, studies of blood flow to the fetlocks of growing foals are yielding valuable evidence of the

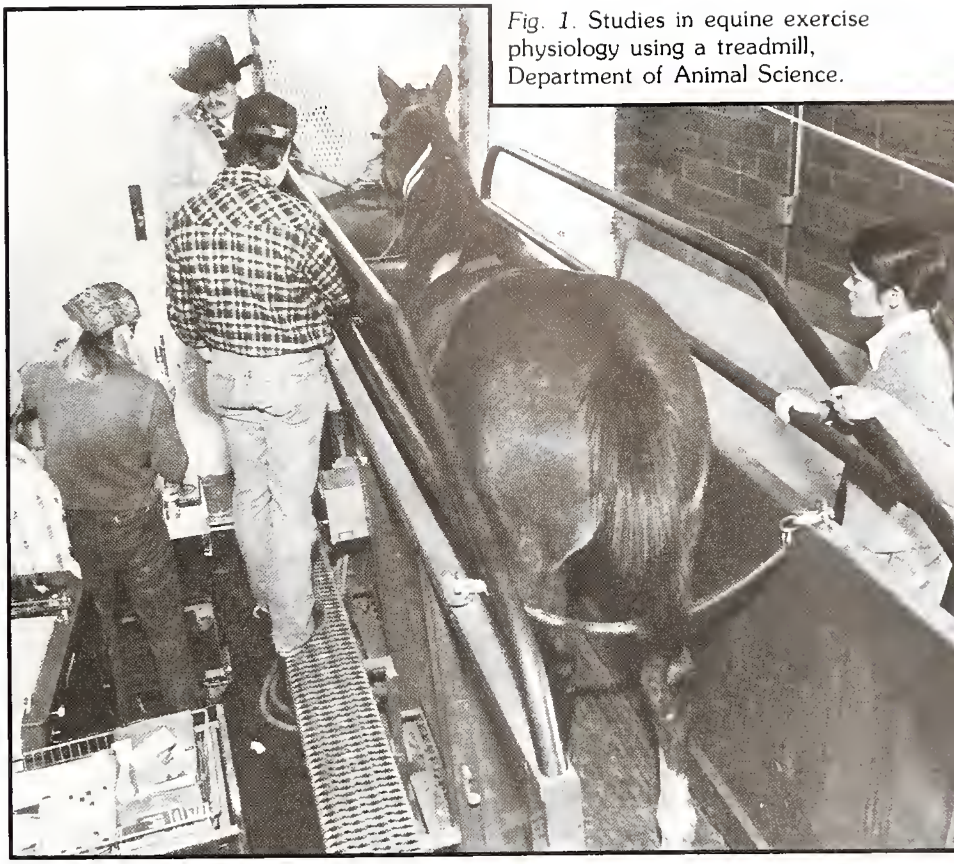


Fig. 1. Studies in equine exercise physiology using a treadmill, Department of Animal Science.

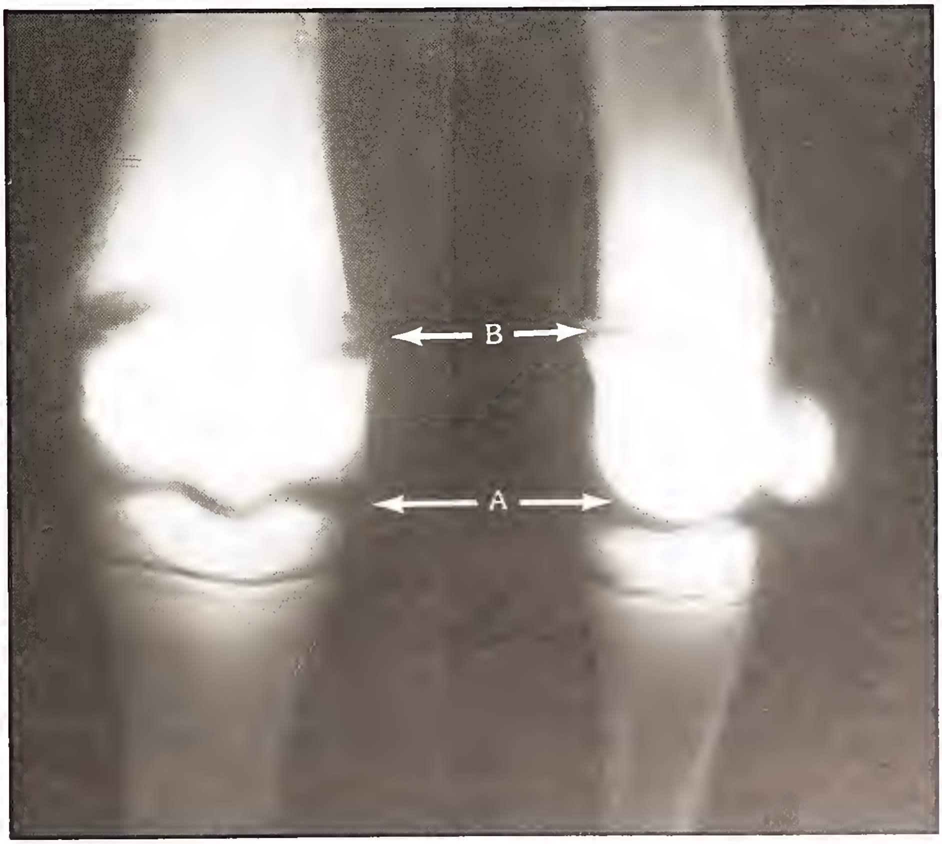


Fig. 2. AP radiographs of a septic epiphysitis in a one-month-old quarter horse foal, frontal view (left) and lateral view (right) of the same fetlock. Note the swollen joint (A) and distorted distal cannon growth plate (B).

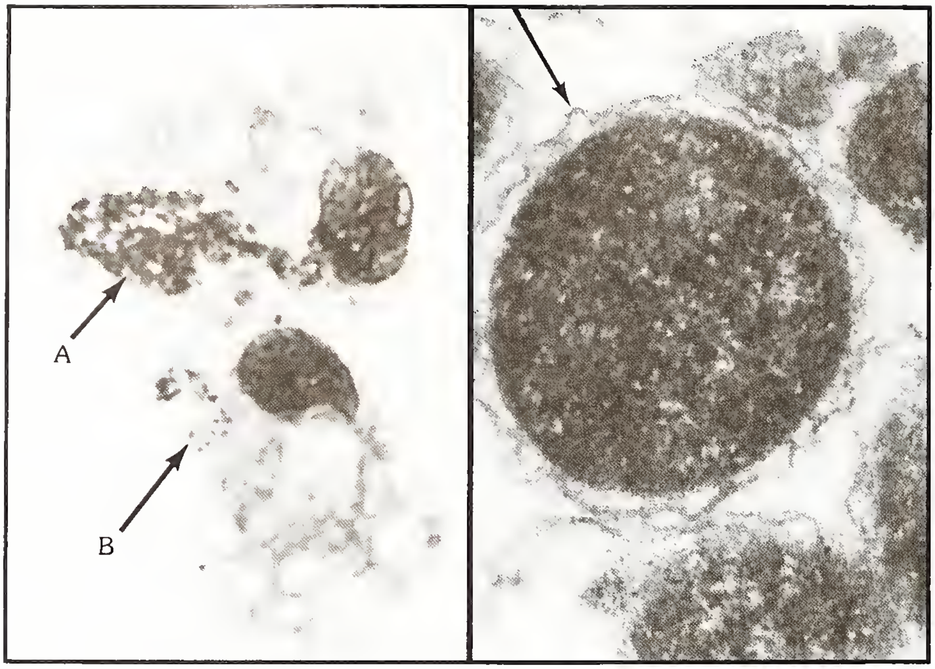


Fig. 3. Left, the organism that causes Potomac horse fever occurs in large clusters (A) or in individual units (B) scattered through the cytoplasm; 1,500x. Right, an ultrathin section shows that the organism is surrounded by a highly rippled membrane; 78,000x.

cause of septic arthritis and osteomyelitis. Examination of blood vessels and tissues taken during autopsy show the location and development of the serious lesions caused by these two inflammatory diseases of the joints and bones (Fig. 2).

In 1979 a new horse disease was reported near the Potomac River in Maryland. Dubbed Potomac horse fever, the disease is characterized by fever, loss of appetite, an abnormally low white blood cell count, and occasional diarrhea. It is fatal in about 30 percent of the cases seen. Over the past five years, many state and federal laboratories have been investigating the cause. Although various bacteria, viruses, and their byproducts have been found in the blood and tissues of the affected animals, none of these agents proved to be the cause of the disease.

Miodrag Ristic and Cynthia Holland in the College of Veterinary Medicine have noted the seasonal occurrence of the disease and have found evidence of antibodies to *Ehrlichia sennetsu* in the serum of convalescing animals. In addition, they have shown that infection may be transmitted in blood transfusions from acutely infected, susceptible horses.

Using this information, Ristic and Holland began trying to isolate the apparent causative rickettsia (bacteria) from the blood of experimentally infected horses and ponies.

Last fall they successfully transmitted Potomac horse fever from an infected pony to a well one. The researchers also isolated the organism, using canine monocyte cultures (Fig. 3), and conducted preliminary serological studies to determine the unique characteristics of this new organism.

The name proposed for the disease is equine monocytic ehrlichiosis (EME). Discovery of the causative agent of EME is a major step towards understanding the origin and development of the disease and finding effective ways to control it.

Now that the antigen has been produced in the laboratory, serological tests can be used to detect all forms of EME and to shed light on how it is spread. Knowing something about the nature of the organism will make it easier for scientists to find drugs to treat the disease and eventually to develop a vaccine to prevent it.

Gordon J. Baker, professor of veterinary clinical medicine

Feeding Our Dogs and Cats

James E. Corbin

Since the preagricultural Mesolithic period, animals have been a source of food, security, and companionship for humans. In modern society, dogs and cats are one of the few remaining links that city dwellers have with the animal kingdom. Today, some 50 million cats and 49 million dogs are kept as companion animals in many of America's 85 million households.

Now that more and more adults are living alone, pets are in a sense replacing family members. The barn cat and the farmyard dog of a past generation have been given a new role as companions in the home. The development of vaccines and controls for parasites along with improvements in nutrition and sanitation have contributed to the acceptance of dogs and cats as desirable surrogates for human companionship.

The pet population has been growing rapidly for several decades. In answer to the demand for even more wholesome pet foods, scientists have succeeded in establishing the nutritional needs of dogs and cats. We have been able to determine precise and relative quantities of required nutrients. Comparative research diets have included crystalline amino acids, vitamins, minerals, and purified fats and carbohydrates. As a result, pet foods are now scientifically formulated in accord with these findings.

During the past ten years, scientists have learned more about the specific amino acid needs of dogs and cats than during the previous ten centuries. Most of these studies have been conducted here at the University of Illinois.

These findings have been accompanied by serendipitous scientific and economic benefits. First of all, in establishing the nutritional needs of dogs and cats, researchers have been able to apply some of these findings

to human needs. For example, nutritionists are gaining a more precise understanding of the relationship among nutrients and the levels required in human diets.

Most of America's pets tend to be better nourished than our children, in part because the nutritional needs of children are still not as well understood. Moreover, dogs and cats, unlike humans, can be fed a single diet throughout an entire lifetime and for generations.

A second, unanticipated benefit from the sharp rise in the number of pets has been seen in the economic sector. Supplying more than 5 million tons (4.5 million metric tons) of dog and cat food annually is a $5 billion business; a similar price tag can be put on veterinary care. Illinois alone produces about 23 percent of the total U.S. output of pet food.

To get some idea of the quantity produced each working day in this country, picture four trains of 114 cars each filled with pet food. An estimated 735,000 tons (656,000 metric tons) of soybean meal and 54.6 million bushels (1.4 million metric tons) of corn are used each year for feeding dogs and cats. A field one mile wide and 1,450 miles long (1 km by 3,760 km) would be required for the soybeans, and another field of the same width and 683 miles long (1 km by 1,770 km) for the corn. Grain sales to the pet food industry are of enormous value to farmers.

America's dogs and cats are living longer and are contributing more to human well-being than ever before. Pets are truly earning their reputation as friends and companions in the home.

James E. Corbin, professor emeritus, animal science

The beagle puppy in the foreground is undersized and shows a loss of some pigmentation in its hair because of a dietary zinc deficiency. Its littermate received appropriate levels.

The paws of the pointer on the left have an abnormality of the horny layer of the skin as a result of too much calcium in its diet. Its littermate on the right received an optimum balance of calcium and zinc.

Views from Industry

The Dairy Industry

An optimist looks at a partly filled glass and describes it as half full, while a pessimist worriedly says it is half empty. As I look at the "glass" called the U.S. dairy industry, I see it as being half full because of one word: research.

Let's look at the tremendous production increases resulting from research. Genetic research has made it possible to breed individual cows that commonly produce more than 20,000 pounds (9,100 kg) of milk a year, or 85 percent more than in 1959. Thanks to nutrition research, dairy farmers can select feeds that lead to healthier, more productive animals.

Other advances can already be seen on the horizon. For example, researchers continue to make improvements in genetic selection to permit maximum response to improved diets. The transfer of embryos into surrogates will become common, making it possible for a superior cow to produce twelve or more high yielding offspring in a single year. Sex selection is also possible through the application of new technology.

Nowadays, cows that produce more than 30,000 pounds (13,600 kg) of milk per year are not unusual. For some reason, though, their offspring are less productive. Scientists are using genetic engineering techniques to find out why, so that we can consistently select for the highest yielding cows.

In recent years, the quality of milk products has greatly improved and new uses have been developed through research. The high quality results from the introduction of sanitary practices, bulk tanks on farm, pasteurization, unit processing, cleaning in place, and improved storage and processing equipment. No other food product so consistently meets consumer expectations. Excellent cheeses are the result of advances in microbiology and proper selection of the microbes used in cheese-making. Today the U.S. cheese industry is one of the finest in the world.

On the horizon we can also see the widespread application of ultrafiltration technology. Its use will allow us to offer new products such as milk that contains less milk sugar. People who have problems digesting milk sugar will then be able to consume dairy products with little or no discomfort.

Yet another development, freeze concentration technology, will provide consumers with frozen concentrated milk. When reconstituted, it will taste like fresh milk and will be just as wholesome. As a means of preserving milk, freeze concentration requires considerably less energy in making milk powder from skim milk.

It is difficult not to be optimistic as we anticipate these advances. But first we must ask ourselves some hard questions about the dairy industry's commitment to research.

Are we doing enough research?

My answer to that question is a resounding no! We have barely entered an era of advancement and change. Research will enable us to anticipate and keep pace with the changes. Our competitors — the makers of imitation dairy products and the dairy industries of other countries — are already investing more money in research than is the U.S. dairy industry.

Are we placing too much emphasis on production research and not enough on product research?

In my opinion, the answer to this second question is yes. Production research is undeniably important, but the dairy industry must balance supply with demand. By stepping up product and process research, we can help boost the demand to match the abundant supply created by production research.

How many research dollars should we be prepared to spend?

We can only find out as we go along. The amount invested by other countries suggests that we should double our current levels. As an investment in the future, research can provide an excellent return on every dollar spent.

Tony Luksas, senior vice president, research and development, United Dairy Industry Association

The Red Meat Industry

Airlines, auto manufacturers, hotels, and many other industries have long recognized that the markets for their products are highly segmented. This fact holds true for the nation's red meat industry as well. According to a study conducted by the research firm of Yankelovich, Skelly and White, meat consumers can be divided into five attitudinal segments: meat lovers (22 percent), creative cooks (20 percent), price-driven (25 percent), active life style (16 percent), and health-oriented (17 percent).

Meat lovers, creative cooks, and price-driven consumers tend to eat meat regularly. People in the active life style and health-oriented categories — a third of all meat consumers — tend to eat meat less frequently. The potential for increasing consumption of red meat is greatest in these last two market segments. They are therefore the primary targets for current demand-building efforts by the red meat industry.

Active life style and health-oriented consumers are interested in leaner meat products. Thanks to modern production practices, U.S. cattle, hogs, and sheep are all marketed much leaner than they were twenty-five years ago. The U.S. Department of Agriculture recently confirmed this trend with a comprehensive nutrient analysis showing that today's beef, pork, and lamb are significantly lower in fat and higher in lean yields.

Today, cattle raised in feedlots produce about 75 pounds (34 kg)

more edible meat per head, an increase of about 27 percent, than in 1950. For hogs, improved muscling and less fat have increased production by about 16.5 pounds (7.5 kg) per animal. The average weight of lamb carcasses has increased more than 22 percent in thirty years.

Most of these improvements were made possible through research in genetics, nutrition, and management. The nation's land-grant universities, such as the University of Illinois, and their research and extension networks deserve much credit for their leadership in helping to make modern production practices possible.

Simply producing leaner meat isn't the only answer, however. The bottom line is that consumers have to want or need our product. And because consumer attitudes and life styles are constantly changing, no product ever has a "lock" on any given market.

The reality of change carries an extremely important message for the livestock and meat industry: Never lose sight of the consumer, the final link in the marketing chain. Clearly, the industry needs to monitor consumer attitudes, life styles, and product preferences closely. Only then can we have reasonable assurance that our products are meeting consumer needs.

In my opinion, understanding the consumer underscores the importance of research. We must have research that helps us produce livestock that meet consumers' wants and needs; research that enables the industry to clearly determine the most effective means of marketing red meat products; and research that enables our products to move through the production, processing, and distribution systems efficiently and profitably.

However, certain research areas will need to be given top priority and support in the years ahead. For example, we must improve reproductive efficiency, gain a better understanding of cellular mechanisms that control protein and lipid synthesis, and develop gene transfer techniques for meat animal production. If we want our land-grant institutions and research centers to continue producing scientific breakthroughs, the industry must support their efforts.

John L. Huston, president, National Live Stock and Meat Board

The Egg Industry

Just forty years ago, eggs were considered a luxury during the winter months. Today, our hens produce eggs year-round. Each hen is also producing more eggs of a better quality than ever before. Now fed a scientifically balanced ration, chickens on average lay more than twice as many eggs as their predecessors of the 1930s. Large farms with environmentally controlled houses have, for the most part, replaced the barnyard flock.

Consumers have reaped the benefits of these improvements. A higher quality product is now available at a lower price in real dollars than was generally paid in the past. Producers are the ones who have had to bear most of the cost of the gains in productivity. Net income per dozen eggs is miniscule at best for the most efficient producers and virtually nonexistent for the others.

Understandably, fewer and fewer farm families are going to the trouble of raising laying hens. In quest of ways to reduce costs, those producers who have stayed in the business are building ever larger egg-laying complexes of one-half million to one million birds.

While often very efficient, these large farms put pressure on the environment. For example, each hen produces about 80 pounds (36 kg) of manure a year. The total amount of waste generated is staggering. Although cleaning out the henhouse wasn't a particularly enjoyable chore even during the days of barnyard flocks, at least there was some satisfaction in using manure to fertilize the garden or cornfield.

The managers of today's laying complexes have a different story to tell: far from being an asset, the waste from their operations has become a major problem. For one thing, it harbors flies and other pests. For another, it creates unpleasant odors that offend the neighbors.

Poultry farmers in some areas are drying the manure either artificially or right in the poultry house, using a modified ventilation system. Once dried, the manure is sold to neighboring farmers. Although a few producers are successfully converting their wastes to assets, most are still searching for solutions.

Questions are also being raised about the welfare of chickens kept in large, environmentally controlled units. The poultry industry isn't alone in its search for suitable housing conditions. Most of the livestock industry has been forced by animal welfare groups both here and in Europe to take a critical look at rearing practices.

Some livestock producers justify their methods by citing the increased productivity of farm animals. On the other hand, people concerned about the welfare of farm animals use human perceptions as a basis for criticizing modern rearing practices and livestock housing. Neither viewpoint is entirely satisfactory. More research is necessary before we can establish guidelines for the humane treatment of farm animals.

Despite the problems remaining, we poultry producers can thank research for many advances made in the industry. Few producers fifty years ago could have imagined how productive hens can be. We hope that researchers will continue to help us meet the challenges and demands of the future.

Kenneth Munroe, egg producer, Will County, Illinois

The Place of Animals in Research

William L. Heckt, Gale D. Taylor, and Stanley E. Curtis

Laboratory techniques that may eventually make test animals obsolete are continually being discovered. To date, however, most of the research and development having to do with animals still requires live animals. Any animal kept for research and teaching can be considered a laboratory animal. Generally bred and raised specifically for these purposes, the animals are housed in environmentally controlled facilities near the laboratories.

One species maintained to provide information about a different species is called a model. For instance, chickens selectively bred for a genetic defect that causes high levels of blood cholesterol are experimental models used in studies related to atherosclerosis in humans. Food- and fiber-producing farm animals used to develop and test agricultural products and techniques are not considered laboratory animals when kept under conditions that simulate commercial production units.

Laboratory animals are valuable in learning about biological processes. Chickens used in biomedical studies related to human health and well-being are kept in carefully controlled facilities.

Laboratory animals. The species used most often in the laboratory are mice, rats, dogs, cats, monkeys, guinea pigs, hamsters, and rabbits. These animals are relatively easy to handle and maintain. Through decades of research, their biology has been studied extensively. Scientists have identified anatomical, physiological, metabolic, and genetic features that are similar to those of other mammalian species, including humans. By studying the biological processes of laboratory animals and developing research techniques, scientists have been able to make important scientific advances that benefit both humans and animals.

Rats are usually selected as models for mammalian nutrition. They are used in the study of dietary nutrient metabolism and the effects of diet on fat deposition, disease resistance, and other bodily functions. Rabbits are commonly used to study reproduction and to develop techniques for in vitro fertilization and embryo transfer. Because mice and rats grow especially fast, reproducing and living long lives within a short period of time, they are effective models for studying many disease processes.

The benefits derived from using laboratory animals can best be described by citing one example among many, in this case toxicology studies. Each year across the nation several million laboratory rats are used to test the safety of thousands of new chemicals. In industry, chemicals are used in controlled manufacturing processes. In agriculture, on the other hand, most chemicals such as pesticides are used in the open air, thus increasing the risk of accidental exposure to humans and animals. These chemicals must be carefully evaluated for their degree of toxicity. They must also be tested to determine whether they can produce cancer after years of low-level exposure.

Safety studies may take five years or more before new chemicals are approved for marketing. During evaluation, the chemical may be injected into the rats, mixed with their feed, painted on their skin, or mixed in their air supply. For some chemicals, each one of these routes of exposure may have to be studied.

Initially, several dosages of the chemical are administered to only a few rats to quickly determine the chemical's basic toxicity. Next, a few dozen rats are exposed for up to 90 days to levels that are tolerated without causing death. The animals are then killed. The organs and tissues are examined during autopsy and under a microscope to identify organs that are specifically affected and to describe the biological effects

Egg production and the management of laying hens are studied on the University's South Farms. Animals used for production research are kept in facilities that simulate farm conditions.

of the chemical.

In the final stage of the study, from several hundred to as many as a few thousand rats are exposed for two years to the chemical, using levels that appear totally safe up to levels that may produce chronic effects. At intervals, some rats from each test group are killed and carefully examined for tumors and for any other effects on tissues.

At the end of the two years, the condition of the exposed rats is compared with that of normal, unexposed rats. Based on the comparison, a judgment is made about the benefits and hazards of using the chemical. The effect of the chemical on developing fetuses, its potential for irritating eyes and skin, and other studies may also be required.

Scientists in the College of Veterinary Medicine use many of these procedures when asked to investigate accidental poisonings. In most emergencies, however, poisoning results from errors in application and dilution or from failure to follow safety guidelines, not from unanticipated hazards of the chemical itself. Research findings can help protect consumers only if they carefully read and follow all directions included on the required label.

Farm animals. In the United States, tens of thousands of farm animals are used annually in various kinds of research, including agricultural experiments in both the public and private sectors. Scientists conducting research related to animal production are fortunate that species important to agriculture can be used directly in experiments; model species are usually unnecessary. Time and money can thus be saved when the species of ultimate interest is used throughout a project.

Depending on the nature of the project, different kinds of animal-holding facilities are needed for research in the animal and veterinary sciences. Some investigations require a very carefully controlled environment in rooms designed for laboratory animals; others call for the wide range of variables found on commercial farms.

Farm animals sometimes serve as models for humans in experimental heart surgery, social behavior, and other biomedical research. Scientists in agricultural experiment stations and elsewhere are now required to keep these animals in the same type of facility required for the smaller species used in similar experiments. The facilities and the care of the animals must meet federal guidelines.

What has been a straightforward situation until now may become complicated, however. Some groups have urged that all farm animals used in research be held only in facilities for laboratory animals, regardless of the type of research (see The Science and Politics of Animal Welfare, *Illinois Research*, vol. 24, no. 4, pp. 15-17).

Standards for farm-animal research facilities are needed, as most agricultural scientists will agree. But in many cases those facilities must simulate conditions on commercial farms; otherwise the results will be biased. The findings of research conducted in inappropriate settings will be of little use to farmers. In the long run, consumers, who are the beneficiaries of agricultural research, will lose out if unrealistic standards are enforced.

William L. Heckt, supervisor of the laboratory animal care program, College of Agriculture; Gale D. Taylor, director of laboratory animal care, College of Veterinary Medicine; Stanley E. Curtis, professor of animal science

Immunology: New Approaches to Old Problems

Keith W. Kelley, Kirk C. Klasing, and Harris A. Lewin

In 1798 Edward Jenner discovered that humans can be protected from smallpox if first infected with cowpox, a similar but less serious disease of cattle. About a hundred years later Louis Pasteur induced protection against chicken cholera, a fatal disease of chickens, by injecting a modified form of a pathogenic bacterium.

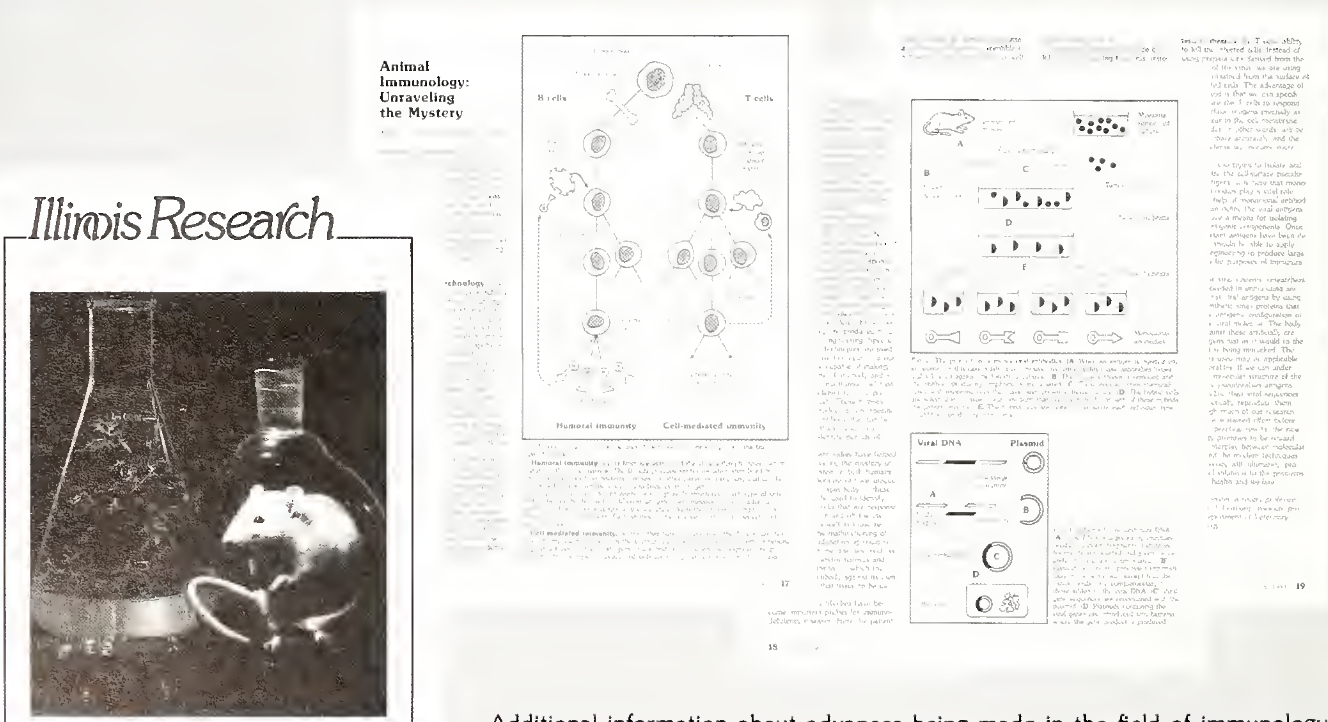
Other immunological research through the years has led to protective vaccines against poliomyelitis, tetanus, measles, and rabies. Once scientists discovered that certain agents can stimulate the human immune system to combat infectious diseases, the field of immunology became an important research area in clinical medicine.

Understandably, people tend to think that immunology is studied only in medical schools. However, this discipline is now recognized as an important basic biological science. Just last year, Georges Kohler, Cesar Milstein, and Niels Jerne were awarded the Nobel Prize for their contributions to immunology. Their research has helped shape our understanding of the immune system and has provided a basis for ways that scientists can manipulate the system for the benefit of humans and animals.

Immunology in animal science. The traditional disciplines in animal science are physiology, nutrition, and genetics. Research in each of these areas has improved livestock production by introducing practices such as artificial insemination, synchronization of estrus for breeding, modern corn-soybean meal diets for nonruminant animals, iron injections for newborn pigs, and crossbreeding and boar-testing programs.

Immunology has at last advanced to the point where it can take its place among these other disciplines. Animal scientists are gradually accepting the fact that the immunological status of an animal is affected by the genes received from its parents, by what it eats, and by its particular physiological state (for example, newborn, pregnant, or lactating). Many problems commonly encountered in the traditional disciplines of the animal sciences can now be studied using immunological techniques. Several examples illustrate this trend:

• The development of methods to produce monoclonal antibodies is an important advance in immunology



Additional information about advances being made in the field of immunology can be found in the article "Animal Immunology: Unraveling the Mystery," *Illinois Research*, vol. 25, no. 4, pages 17 to 19.

(see Animal Immunology: Unraveling the Mystery, *Illinois Research*, vol. 25, no. 4, pp. 17-19). Using this technology, scientists can easily obtain large quantities of pure antibodies from immortalized cells that produce antibodies of desired specificity.

Monoclonal antibodies are now routinely used in human and animal research. Within the last year, for example, they were used for the first time to protect newborn calves against a deadly and costly diarrheal disease.

- Hormones dramatically affect animal growth and reproduction. We realize now that they affect lymphoid cells as well and that lymphocytes themselves secrete a variety of hormonelike molecules. Scientists are actively studying the mechanisms by which lymphocyte hormones affect disease resistance and animal growth.

- Researchers recently began "vaccinating" animals with hormone-specific antibodies to reduce the levels of certain hormones. For example, an animal can be castrated without surgery ("immunocastrated") by suppressing the hormone needed for the production of sperm.

- Inadequate nutrition often accompanies sickness and malaise. We're learning that diet has a dynamic effect on an animal's immune response and that supplementing the diet may step up the activity of the immune system. The entire area of nutrition and immunology is ripe for study.

- The percentage of prenatal deaths in all domestic species is very high. Animal scientists are beginning to ask whether immunologic reactions during fetal development contribute to the tremendous loss.

- An animal's ability to develop immune responses depends in part on its genetic background. This finding has opened up the possibility of breeding animals with stronger resistance to infectious diseases. Eventually we may even find the genes themselves and insert them into embryos.

Clearly, if the immune system is to perform at its best, an animal's physiology, nutrition, and genetic makeup must be optimal. Picture those three components as the legs of a stool (Fig. 1). Removing or shortening a leg causes the stool (that is, the immune system) to become unstable. Indeed, researchers must continue to examine how these components are related to the immune system so that further advances in production efficiency can be made.

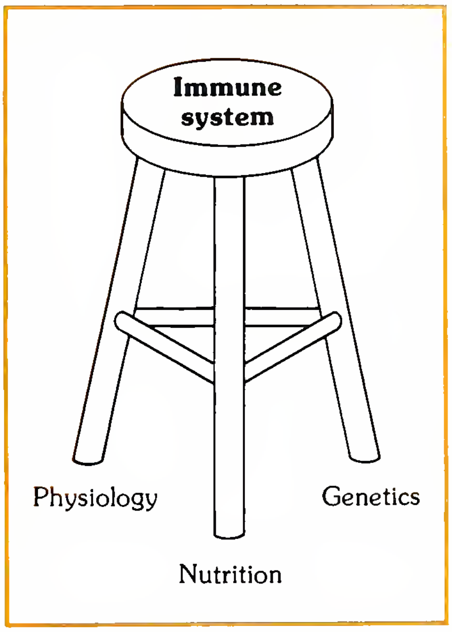


Fig. 1. The immune system of an animal is affected by its physiology, genetics, and nutrition. An imbalance of these three elements makes the entire system unstable.

Let us turn now to specific immunological research in animal science. The objectives of this work fall under the traditional disciplines of physiology, nutrition, and genetics.

Physiology. Twenty-five years ago a good animal husbandman had a sixth sense when it came to caring for livestock. If the bedding was wet, he crawled into the hayloft and threw down dry straw to bed the cows. After chores on a snowy night he carefully closed the doors of the hog house. Perhaps he got up at two o'clock in the morning to check on a ewe giving birth.

In those days, common sense dictated what biologists are only now starting to understand from the scientific point of view. Preventing disease requires taking into account three things: the pathogenic organism, the physiological state of the host, and environmental conditions. While a microbe is needed to cause an infectious disease, the severity can be modified by the other two factors.

To illustrate the point: in one experiment three-week-old pigs were kept in a warm area and another group in a cold area. Both groups were then infected with bacteria that cause diarrhea. Two-thirds of the cold-stressed pigs developed diarrhea, compared with only one-third in the group kept warm. Furthermore, the growth rate of the cold-stressed, diarrhetic pigs was reduced by one-third.

These findings show that exposure to cold can increase a pig's susceptibility to one of the most costly swine diseases on Illinois farms. Just as importantly, the findings supply scientific evidence for the common-sense observations of pork producers.

Researchers at the University of Illinois are now trying to pin down exactly how environmental conditions affect susceptibility to disease. Their research has shown that the normal functioning of the immune system is altered by heat and cold, shipping, weaning, and stressful psychological situations.

This type of research can also benefit humans. The findings may ultimately explain how mental states such as depression, anxiety, or fear are involved in the development of infectious, autoimmune, or neoplastic diseases.

A most promising area of study is the apparent link between stressful environmental stimuli and the immune system. So far, research has shown that certain hormones are secreted during stress. These stress hormones are believed to interfere with the normal development or function of lymphocytes and may alter some types of lymphoid cells, thus increasing susceptibility to disease.

In another exciting finding, lymphoid cells themselves have been shown to secrete a stress hormone called ACTH (adrenocorticotrophic hormone). The same cells secrete two other hormones, TSH (thyroid-stimulating hormone) and HCG (human chorionic gonadotropin), a clas-

sic hormone involved in reproduction (Fig. 2).

Some of these hormones are in turn affected by small, hormonelike protein molecules called cytokines that are secreted by lymphoid cells. Studies of how these cells communicate will almost certainly yield important practical benefits in stress physiology, nutrition, and reproductive physiology.

Nutrition and growth. Research in nutrition has greatly benefited animal producers. Nutritionists have discovered which nutrients are required, the amounts found in various feedstuffs, and how much of each nutrient an animal must consume for maximum growth and for the production of wool, milk, or eggs.

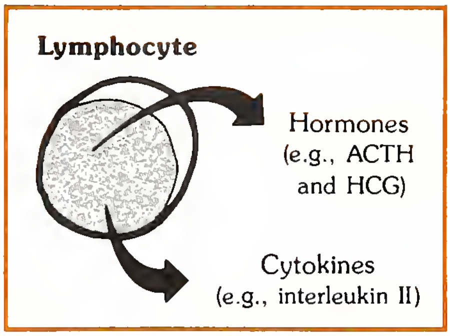
The minimum amount of energy necessary for maximum production has been tabulated for most species of farm animal, and the thirteen vitamins, fifteen minerals, and twelve amino acids required have been identified. Growth rate, milk or egg yield, and other production parameters have been taken into account because of their direct relationship to efficiency and profitability.

Nutritionists are now asking if they can improve upon these nutrient requirements. For example, will an animal's immune system perform at a peak level on a diet that maximizes its growth rate? Or is it possible that more nutrients might be needed for the immune system to effectively combat invading, disease-producing organisms? If so, then current nutritional recommendations may be too low.

Fortunately, the levels of most nutrients already tested are adequate to maximize immunocompetence as well as growth. There are some exceptions, however. For instance, sheep, chickens, and turkeys can fight off infections caused by *Escherichia coli* and *Chlamydia* more effectively when given dietary vitamin E at several times the dosage required for maximum growth. The same can be said of vitamin A.

Although only a few of the twelve essential amino acids have been examined, the quantities needed for top growth appear adequate for im-

Fig. 2. Lymphoid cells have recently been found to secrete the stress hormone ACTH. They also secrete cytokines such as interleukin II, which can trigger the immune response.



munocompetence. Valine and threonine are perhaps exceptions, and supplements may be necessary when an animal is challenged by disease.

The quantity of feed an animal eats during any given day influences how well the immune system works during that day. In animals that are not fed for short periods before or after a disease challenge, antibody response to experimental antigens is enhanced. Conversely, in animals that overeat near the time when challenged, the ability to mount an immune response is impaired. Of course producers, not knowing when a challenge will come, can't routinely exploit this relationship. When vaccinating, however, they can make sure the animals are appropriately nourished.

The immune system in turn can modify nutritional needs and growth or production capabilities. When the immune system is stimulated by bacteria, viruses, or parasites, for example, the cells involved in the immune response release hormonelike substances (cytokines) that cause a change in metabolism. The change alters nutritional needs and growth or production rates.

The best understood of these cytokines is interleukin I. Produced by macrophages (the body's scavenger cells), it can trigger the immune response. It also causes the animal to produce more heat by raising the thermostat in its hypothalamus. Energy originally derived from the diet is used during the process, which can be measured as a higher basal metabolic rate. Interleukin I also hinders the accumulation of protein in skeletal muscle. As a result, muscles grow more slowly.

Other chemical messengers, produced when the immune system is stimulated, trigger the release of catabolic hormones from the endocrine system. Elevated levels of two of these hormones, glucagon and glucocorticoid, impair muscle growth. Slower growth plus a greater need for energy to support a high basal metabolic rate means that less meat is produced per pound of feed. Consequently, profits are lower.

Well aware that production losses occur during disease outbreaks, commercial producers take preventive measures. However, losses in production efficiency do occur to some degree even in apparently healthy herds or flocks. Animals are bombarded every day with disease-producing organisms that the immune system intercepts and wards off.

Greatest when cleanliness and hygiene are not strictly observed, these challenges stimulate the release of mediators from the immune system, thereby depressing meat, milk, and egg production. Producers can minimize the challenge by scrupulous observance of good hygiene, which enables the animals to perform closer to their genetic potential.

When antibiotics are added to animal feed, growth rates improve and feed is utilized more efficiently, particularly when sanitation is poor. Antibiotics are probably effective because they make the animal less vulnerable to organisms that stimulate the production of substances which impair performance and increase feed costs. However, some organisms may become resistant to antibiotics. If these resistant organisms enter the food chain and infect someone, effective treatment may be difficult if not impossible. By understanding how antibiotics improve performance, we hope to find other, less problematic ways of boosting animal production.

Immunogenetics. As in all biological sciences, genetics is a foundation of immunology. Certain genes are necessary to generate and regulate immune responses. In an envi-

ronment full of disease-causing organisms, the survival of all vertebrate species depends upon the proper functioning of these genes. Immunogeneticists hope to identify, localize, and perhaps someday clone them. Using classical animal breeding and biotechnology, we now expect to move ahead rapidly.

Immunogeneticists can be divided into two main camps:

- those who use immunological methods to study the products and actions of specific genes (let's call this group type I immunogeneticists)
- those who analyze how specific genes work to produce normal and abnormal immune responses (type II immunogeneticists)

The discoveries made by both groups have revolutionized human medicine and animal agriculture. A brief foray into the recent past can help us understand what has led to the most exciting time for animal agriculture since the discovery of cheese.

Blood groups: the birth of immunogenetics. In 1930, thirty years after his initial breakthrough, Karl Landsteiner (type I) received the Nobel Prize for discovering the human ABO blood groups. Thanks to his work, we can safely transfuse blood from one individual to another. More recently, it has been shown that blood groups must be matched if organ transplants are to succeed.

Landsteiner and his associates also discovered the Rh blood groups and their role in hemolytic (blood-killing) disease of newborn humans. Animal immunogeneticists later showed that newborn horses and pigs can develop a similar disease, which is also associated with incompatible blood groups. We can now use blood typing to identify mating pairs at greatest risk of producing an incompatibility between mother and offspring. In humans, effective preventive measures can be taken before birth. In animals, a simple test can identify newborns at greatest risk of developing hemolytic disease.

The 1940s, 1950s, and 1960s saw an explosion in our knowledge of animal blood groups. Clyde Stormont and his disciples (type I) devoted themselves to studying blood groups of cattle, pigs, horses, sheep, and goats. Their work has resulted in the most powerful method for animal identification and paternity testing.

Cattle and horses have blood group systems that are remarkably complex. Every cow and horse has, in effect, a unique blood type. Hence, many breed registries require blood-typing information. Blood-typing services have become a multimillion dollar industry in the United States.

Genetic control of the immune response. Today's type II immunogeneticists are totally absorbed in studying genes that determine the nature of the immune response. Yet interestingly enough, these genes were discovered in a roundabout way. During the 1950s, scientists found that rejection or acceptance of skin grafts is determined by genes located on a single chromosome. Other scientists later on showed that a cluster of closely linked genes on chromosome number 17 of the mouse determines whether the skin transplants are accepted or rejected. This cluster was thus named the major histocompatibility complex (MHC).

In the early 1970s, scientists made the startling discovery that genes within the MHC determine whether an effective immune response can be mounted when animals are challenged with different types of antigens. The mouse MHC was also found to contain genes that control normal embryonic development, along with genes that influence mating preference, growth rate, and other traits.

The human MHC has been linked with susceptibility to diseases such as ankylosing spondylitis (a crippling arthritic disease of the spine), multiple sclerosis, diabetes mellitus, rheumatoid arthritis, and certain types of cancers, to name but a few. The human MHC is known as the HLA (human leukocyte antigen) system. In 1980, George Snell, Jean Dausset, and Baruj Benacerraf (types I and II) were awarded the Nobel Prize for work on the MHCs of men and mice.

These findings rocked the world of animal genetics. Could the genes for disease susceptibility be identified in domestic animals? And if so, could we use these genetic markers to select healthier and more productive animals? The answer to both questions turned out to be yes.

In the 1960s, scientists began selection experiments to see if a chicken's resistance or susceptibility to the paralyzing Marek's disease is a heritable trait. In successful experiments at Cornell University, two lines of chickens were produced, one highly resistant to the disease and the other highly susceptible.

In 1975, to the astonishment of everyone, all the resistant chickens were found to share the same blood type called B^{21}. The B group, to which this blood type belongs, was later identified as a product of the chicken MHC. Birds and reptiles have MHC products on their red blood cells, while in other species MHC molecules are expressed on lymphocytes, a type of white blood cell.

By selecting for resistance to Marek's disease, these scientists unknowingly selected for common genes at the MHC as well. This marker system in the blood was later used to select for commercial breeds of chickens with natural resistance to the virus that causes Marek's disease. The layer and broiler industries now have fewer disease outbreaks, and economic loss has declined as a result.

Work on the MHC of large farm animals has been slow, because they are expensive to maintain and don't reproduce quickly. Some important progress has been made, however. In horses, for example, lameness seems to be associated with a particular ELA (equine lymphocyte antigen) type. In pigs, differences in their ability to develop immunity when vaccinated for atrophic rhinitis may be associated with the SLA (swine lymphocyte antigen) system.

In cattle, resistance and susceptibility to leukemia are linked to the bovine MHC, as a University of Illinois scientist has found. Bovine leukemia is caused by a virus distantly related to viruses that cause leukemia and AIDS (acquired immunodeficiency syndrome) in humans. The knowledge gained from cattle may help us devise effective methods for treating and controlling these important diseases.

We have barely touched the tip of the iceberg, yet we have great hope that other markers for disease resistance and for increased productivity can be found. What will we do with this knowledge when we master it?

Biotechnology: the high frontier. New biotechnologies can result in the rapid spread of desired genetic traits. Immunogenetics, coupled with the powerful techniques of embryo splitting and transfer, offers unparalleled opportunity for progress. For example, we will be able to select embryos that carry desirable genes. Since MHC gene products are also expressed on the cells of early embryos, we can use MHC markers to breed cattle for increased resistance to specific diseases and with desirable production traits (Fig. 3).

Scientists are on the threshold of being able to determine the sex of embryos before transferring them into hormonally prepared females. Antibodies that recognize an antigen expressed only on male cells can be used to separate male embryos from ones destined to be females. Dairy producers will be able to choose female embryos only, and beef producers male embryos.

Add recombinant DNA technology to the methods discussed above, and we will be able to genetically engineer animals to meet our needs. Cloning desirable genes — like the MHC-linked genes for disease resistance — and introducing them into embryos or perhaps into rapidly dividing blood cells can lead to the development of "superspecies."

Although this work may sound a little like "immunoastrology," we had better familiarize ourselves with the technology. We as a society must know the ethical arguments pro and con before deciding to proceed with these types of manipulations. The decisions we make today may very well determine whether people will have enough meat and dairy products for good nutrition in the next century.

Keith W. Kelley, professor, and Kirk C. Klasing and Harris A. Lewin, assistant professors, Department of Animal Science

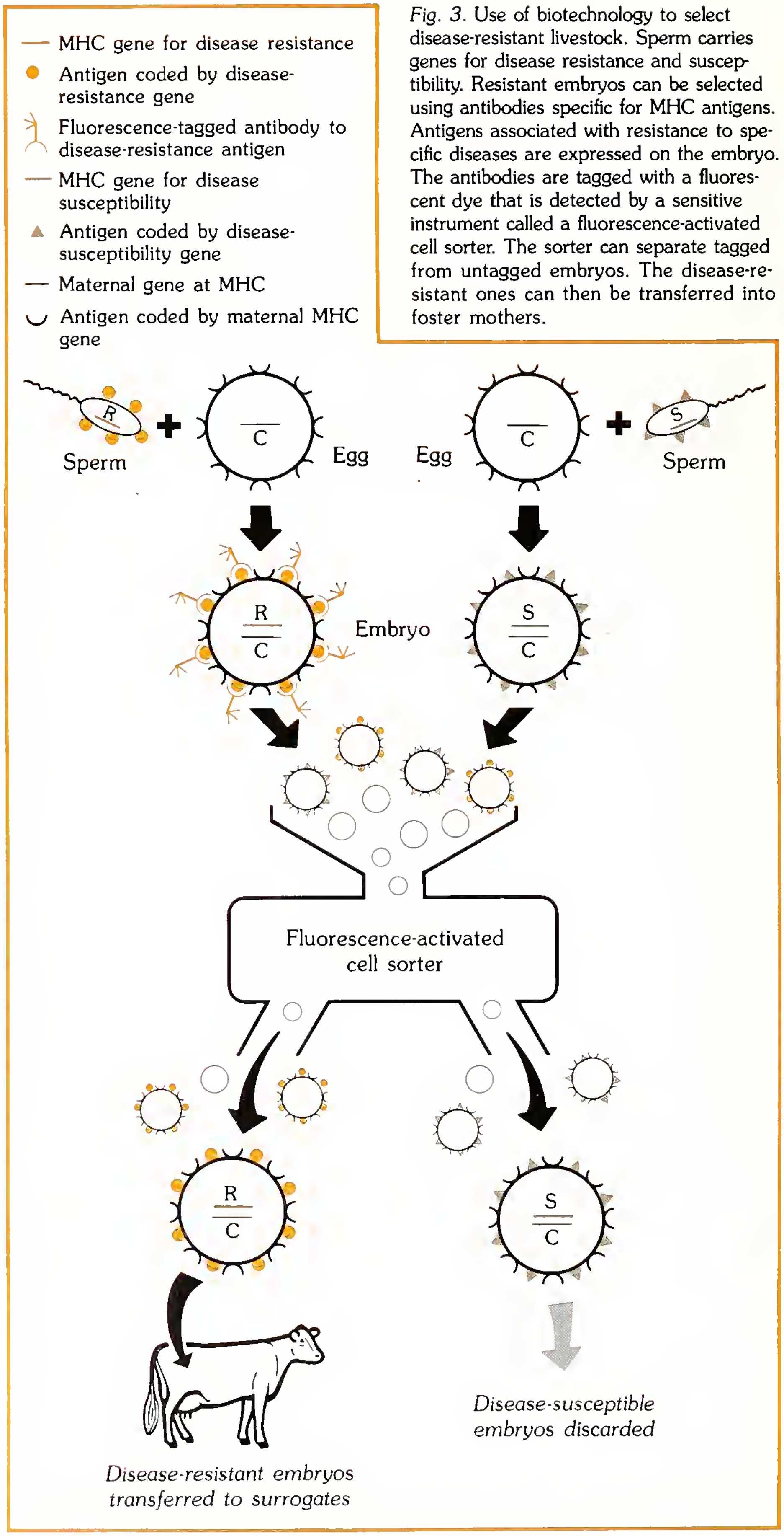


Fig. 3. Use of biotechnology to select disease-resistant livestock. Sperm carries genes for disease resistance and susceptibility. Resistant embryos can be selected using antibodies specific for MHC antigens. Antigens associated with resistance to specific diseases are expressed on the embryo. The antibodies are tagged with a fluorescent dye that is detected by a sensitive instrument called a fluorescence-activated cell sorter. The sorter can separate tagged from untagged embryos. The disease-resistant ones can then be transferred into foster mothers.

Update

Policy and Preferences in 1985

Robert G. F. Spitze

An historic year is in store for the nation's agricultural and food sector. Beginning with the severe and widespread farm financial crisis, the year is likely to end with another comprehensive public policy that will affect farmers, consumers, agribusinesses, exporters, and taxpayers. During the intervening months, the preferences of these many groups will help shape policy for the rest of the 1980s.

Now that the President has been inaugurated and the 99th Congress installed, final steps are being taken to develop a new policy to succeed the Agriculture and Food Act of 1981. The 1981 act evolved, through many intermediate acts, from the first policy in 1929, which focused directly on farmer prices and incomes. Scheduled to expire on September 30, the current act set policy for our food stamp program, foreign food aid, national grain reserves, and commodity price-income and production-balancing programs for all grains, cotton, peanuts, wool, and dairy products. It also touched on agricultural trade, education, research, credit, soil conservation, and even floriculture.

Interest in the 1985 price and income policy already seems to be more widespread and intense than ever before in the policy's history. At this stage, however, it is difficult to predict whether a 1981-type policy will be continued or whether an alternative will be chosen. Possible alternatives range from phasing out all such policies to greatly expanding them. Many options are surfacing and numerous background studies, conferences, publications, and surveys are providing the greatest knowledge base ever.

The cycle four years ago gives us some clues about the pattern to be expected for the process now under way, although our predictions could be confounded by the crisis in the farm financial situation and in the federal budget deficit. Barring the unexpected, however, committee bills will be reported now that the Administration has announced its proposal for new policy and after the Senate and the House agriculture committees involve hundreds of interest groups in extensive public hearings.

The bills will probably be presented to the Senate and House chambers by summer. Consensus will be difficult at best, however. A conference committee formed of both bodies will enter into protracted negotiations to search for a majority compromise, fully aware of a possible presidential veto.

This process could take even longer than the marathon sixteen conference days for the 1981 act. If a compromise is not reached before September 30, the 1981 act may have to be extended into late 1985 or early 1986. With planting deadlines always approaching, stopgap measures may be necessary.

During this lengthy process, numerous interest groups and individuals will be expressing their preferences through our participatory system in an effort to influence the outcome. Throughout the past year, University of Illinois researchers have conducted innovative national studies to ascertain the views of selected groups. The findings are presented in three publications:

- *U.S. Farmers' Views on Agricultural and Food Policy* by H. D. Guither, B. F. Jones, M. A. Martin, and R. G. F. Spitze, North Central Regional Research Publication 300
- *How Illinois Agribusiness Views Agricultural and Food Policy Issues* by H. D. Guither, Illinois Agricultural Economics AE-4573
- *National Leaders' Views on 1985 Agricultural and Food Policy* by R. G. F. Spitze, Illinois Agricultural Economics 84 E-305

Requests for copies of these publications should be addressed to: University of Illinois, Publications, 305 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801.

Information in *National Leaders' Views* is based on a survey of more than 450 leaders of national farmer organizations, agribusinesses, commodity promotion councils, state directors of agriculture, state directors of the Agricultural Stabilization and Conservation Service, consumers, general citizen organizations, and agricultural policy economists. The respondents generally favor a governmental intervention policy in the agricultural and food sector for many public issues such as food assistance, grain reserves, commodity prices, and farmer incomes, along with trade, farm credit, soil conservation, and agricultural research and education.

The respondents generally oppose a governmental intervention policy to make public payments supporting farmer incomes, to authorize farmer collective bargaining, to regulate farm size, and to embargo exports. In summary, the leaders who were surveyed favor specific provisions similar to the 1981 act, but with important changes such as more flexible loan and target levels and cross compliance between benefits and soil conservation practices.

The 1985 agricultural and food policy that is eventually developed will represent a protracted, difficult, and narrowly won compromise for that point in time. In our participatory system, the choice should be considered an expression of the public interest developed from the highly diverse interests of private groups and individuals.

Robert G. F. Spitze, professor of agricultural economics

In Progress

Funk awards

Three College of Agriculture staff members were cited for "outstanding service to agriculture" in the fifteenth annual Paul A. Funk Recognition Program, held in Urbana on March 4. Each citation was accompanied by a cash award. Funds for this program are provided by the Paul A. Funk Foundation of Bloomington, Illinois.

Constantin A. Rebeiz is internationally known for his pioneering work in the biosynthesis of chlorophyll. His research in this area has led to the development of laser herbicides, which have received worldwide attention.

Duplicating the greening process in a test tube has been one of Rebeiz's major achievements: he has developed cell-free systems capable of synthesizing cholorophylls *a* and *b*. His new spectroscopic and analytical techniques and equations have demonstrated unambiguously the existence of several new chlorophylls and of several biochemical pathways of greening in higher plants.

Rebeiz is applying his knowledge of the greening process toward improving plant productivity. This effort, as well as his concept of a cell-free agriculture, could revolutionize world food production.

John T. Scott, Jr., is recognized as a state and national authority on farmland values in the Midwest. He has made several notable contributions to agricultural economics. In particular, Scott has focused on the use, marketing, tenure, and taxation of farmland.

He has developed practical procedures for assessing real estate taxes on Illinois farms and has been instrumental in bringing about real estate tax reform for farmland in Illinois. His new financial approach to estimating farmland values has been adopted by leading appraisers.

Scott's contribution to statistical methodology has brought him international recognition. His Factor Analysis Regression is a statistical model that has been widely cited in economic texts. He has also made a valuable contribution to mathematical programming.

Darrell A. Miller has acheived distinction as an outstanding teacher of agronomy and as an authority on forage crops. As teaching coordinator in the Department of Agronomy, Miller has played an important role in decisions affecting courses and curricula, student advising, teacher evaluations, and course scheduling and content.

Known throughout the state and nation for his research on forage crops, he has recently published a textbook on the subject. His plant-breeding program has led to the production of six germplasm pools of alfalfa that have been used in cultivars throughout the country.

Miller's nitrogen studies have shown that alfalfa crops significantly reduce the potential for contamination of soil and water. His research on autotoxicity in alfalfa has helped increase production in the state.

Iron and the immune response

Iron deficiency is widespread among infants, children, and adult women. Adria Sherman, Department of Foods and Nutrition and the Division of Nutritional Sciences, is currently studying the role that iron plays in the immune response and in protein synthesis.

Sherman and her research group have found that the suckling pups of iron-deficient rats have trouble producing antibody after being immunized with a foreign antigen. Correcting the deficiency after the rats are weaned doesn't totally repair the problem.

The researchers have been exploring the mechanisms by which iron contributes to antibody production. So far they have found that in the newborn of iron-deficient rats the cells of two key organs don't develop normally. One of the organs, the spleen, is directly involved in antibody formation. The other, the thymus, is indirectly involved through production of specialized T cells.

However, reduced cellular development does not totally explain why antibody synthesis is defective, Sherman says. Even when there is significant improvement in the spleen cells after feeding the rats adequate iron, antibody synthesis is still compromised.

Protein synthesis, a related mechanism the researchers are exploring, is also defective. They have found that protein synthesis in the liver, spleen, and thymus is significantly impaired in iron-deficient rat pups. Since antibody is a specialized class of protein, its synthesis is likewise impaired.

Apparently adequate iron is required for antibody synthesis and for protein synthesis, two functions of iron that were not identified before. Iron deficiency often arises when the diet doesn't contain enough iron. Nutritional guidelines should therefore deal specifically with iron intake, Sherman says.

With its larger flower, the 'Mona Lisa' anemone (left) is a considerable improvement over the older 'de Caen' cultivar (right). The 'Mona Lisa' also has a longer, stronger stem.

The Mona Lisa on display

In a seldom visited corner of campus, the Mona Lisa smiles enigmatically on the chance visitor. In this case, however, the name refers not to the 16th century painting by Leonardo da Vinci, but to a type of cut flower. A Dutch introduction, the Mona Lisa anemone (*Anemone coronaria* 'Mona Lisa') is now being tested in a horticulture greenhouse.

The cultivar is special because it is a tremendous improvement over the species and two older cultivars, 'St. Brigid' and 'de Caen'. Improvements include a more vigorous plant, a stronger and longer flower stem, and a larger, more striking blossom. It comes in a wide array of glowing colors from white, rose, and red, to purple and blue, with some bicolors.

Holland is outstanding for its active and progressive breeding of cut flowers for the international florist and greenhouse industry. The University of Illinois Department of Horticulture grows many new Dutch varieties to evaluate them and to introduce them to cut-flower growers in Illinois and the Midwest. Floriculture faculty members involved in this exchange are Marvin Carbonneau, who arranges for shipment of the crowns, bulbs, or rootstocks, and Dianne Noland, who uses and evaluates cut flowers in floral designs.

Other new cut-flower varieties grown in University greenhouses include the Peruvian lily (*Alstroemeria aurantiaca*). Relatively unknown in the United States, this long-lasting flower is now becoming more popular, particularly the 'Rosario' and 'Zebra' cultivars. The azalealike flowers appear on many flowering stems above leafy stalks. Bright with an exotic look, the flowers are yellow, orange, red, rose, or white with brown or red flecks.

A Dutch introduction made five years ago has greatly increased the popularity and use of freesia (*Freesia* spp.) in Illinois. Delightfully fragrant with good keeping qualities, the freesia bears many individual florets that open along an arching stem. The color range encompasses the full spectrum of the rainbow, including an interesting brown and many bicolors.

The Mona Lisa anemone, the Peruvian lily, and freesias are grown in cool greenhouses at temperatures averaging 50°F (10°C). The introduction of new Dutch flower varieties to Illinois and the Midwest is one of many valuable services provided by members of the floriculture faculty for Illinois florists and greenhouse growers.

Dianne Noland, lecturer in horticulture, displays the 'Rosario' Peruvian lily, which is a bright, exotic-looking cultivar. It is white and rose-pink with dark flecks.

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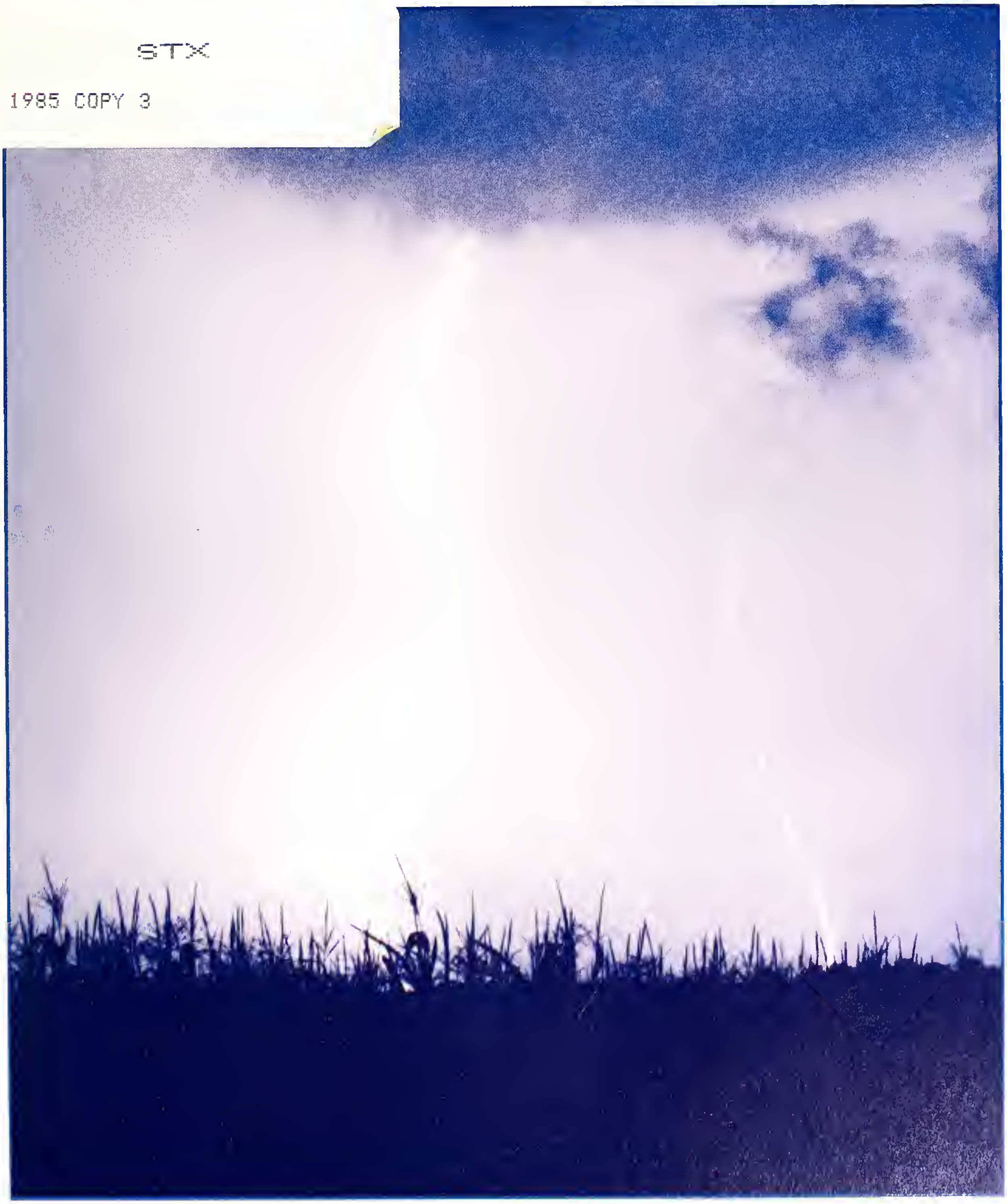
Illinois Research

Summer 1985

The weather:
how it affects
people, plants,
and animals

Illinois Research

Agricultural Experiment Station
Summer 1985



College of Agriculture, University of Illinois at Urbana-Champaign, Volume 27, Number 3

1985 - Directions - 1995

A Scientific Look at the Weather

Since humans first emerged from the caves, we have realized that the weather greatly affects our lives and fortunes. Yet surprisingly enough, we haven't learned much about these relationships. How is a cattle farmer, for example, affected by a 10-inch (25.4 cm) snowfall in mid-December, a dry spell in early March, or temperatures above 90°F (32°C) for eight consecutive days in July? We have some qualitative answers but very little quantitative information about specific effects of the weather on our health, homes, environment, and economy.

Scientists from the Agricultural Experiment Station, the Illinois State Water Survey, and the Illinois Natural History Survey are attempting to answer these and many related questions. For example, team members are studying the relationships between weather conditions and the movement of insect pests. The knowledge gained is providing more accurate forecasts for parts of Illinois and the time and extent of insect outbreaks.

Others in the group are defining how weather affects crop yields under current farming practices. This work will help farmers adjust their management practices to average and extreme weather conditions. In yet another project, the focus is the way that farmers make weather-related decisions. The researchers hope to learn the degree of accuracy needed in long-range weather predictions and when the reports should be issued.

Our weather research program is developing rapidly. In the next five to ten years we will see many advances in understanding the effects of the weather. Atmospheric findings will benefit Illinois agriculture in three areas. First, weather and climate information will be more detailed, accurate, and timely. The two Surveys are developing a new climate information system for agriculture. The system will provide constantly updated weather, water, climate, and pest information to extension agents and to anyone else with a terminal.

Second, better weather predictions will become available both for the short and the long term. The need that farmers and agribusinesses have for predictions is guiding our research at the Water Survey. We are now issuing monthly and seasonal precipitation outlooks for various areas of Illinois.

And third, the atmospheric sciences can help Illinois by modifying the weather through suppressing evaporation from our ponds and crops, by irrigation, or through modification techniques such as cloud seeding. In a major research program, the Water Survey and the Experiment Station are working together to determine the potential for increasing summer rainfall to enhance Illinois crops. Within the next ten years, a field experiment should be completed to provide information about how to do cloud seeding in Illinois.

Stanley A. Changnon, Jr., chief, Illinois State Water Survey

The Cover

Lightning plays across the evening sky during a midsummer thunderstorm in Champaign County, Illinois. This part of the state is visited by more than forty thunderstorms throughout the course of a year. Hail, tornadoes, freezing rains, and snowstorms are also common. Intensive research is now under way to determine scientifically the effects of the weather on crop and livestock production.

The photograph on the cover was taken from a full-color, limited-edition photograph by Larry Kanfer, Champaign, Illinois. Mr. Kanfer currently has works on display in the rental galleries at the Art Institute of Chicago.

"At a time unlike any in the past, we must envision the future."

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Letters

To the editor:

I very much appreciate the information in *Illinois Research*, and have made use of it often in teaching. I have one suggestion, though. In Volume 27, number one [on international agriculture], you use a world map. Perhaps you should change from the Mercator projection of this map. Mercator projections are known to distort (increase) the extent of the northern hemisphere and diminish the south. It was especially disturbing to see this cartographic projection in a volume addressing the agro-economic problems of developing countries. Perhaps you should make use of the Peters projection or the Tripel projection, both of which more accurately portray the size of continents and land masses.

Additionally, the map you use indicates Transkei, one of the "homelands" the government of South Africa has created to further its policy of apartheid. The United Nations does not recognize these homelands as independent countries. Why should the University of Illinois College of Agriculture do so?

Sonja L. Williams
Urbana, Illinois

The choice of projection was based on the need to have room for type of a legible size; otherwise, many country names could not have been included. Your point about Transkei is well taken. Thank you for calling it to our attention. — Editor

Address communications to Editor, Illinois Research, University of Illinois at Urbana-Champaign, 47 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801.

Please limit letters to 250 words.

The Weather

The Weather and Climate of Illinois

Stanley A. Changnon

Illinois is a favorite spot for atmospheric scientists who want to study the weather. Practically every kind of weather condition known throughout the world can be found right here during the course of a year. We have thunderstorms, hail, high winds, and tornadoes in the spring and summer; awesome blizzards in the winter; and pollution that makes matters worse year-round.

Anyone who has ever lived here can vouch for the hot, humid summers and bitterly cold winters, the torrential rains, and the widely and rapidly fluctuating temperatures that sometimes catch us off guard. "If you don't like today's weather, just wait till tomorrow," Illinois residents tell their visitors.

Continental climate. The Illinois climate is controlled primarily by solar energy and the weather systems with their varying air masses and storms. Hills, cities, and forests have considerably less influence on our climate, but more about these later.

In the 19th century, European climatologists compared the limited weather data available from around the world and then derived averages and extreme values. From this information they developed worldwide climate classifications. All areas on the interior of continents have similar conditions with great extremes. These continental climates, as they were called by the 19th century climatologists, differ considerably from marine climates, which are moderated by nearby oceans or large lakes. The continental climate of Illinois is marked by a wide range of temperatures, with cold winters and warm to hot summers.

Air masses. Illinois is frequently visited by two opposing air masses, one generated or modified over the continent and the other over the Gulf of Mexico (Fig. 1). The warm, moist air from the Gulf contrasts markedly with the northern air, which can be bitterly cold in winter.

The resulting battle of the air masses accounts for the cyclonic, low-pressure storms that plague Illinois about a hundred days each year. Interaction between these two sharply contrasting masses produces storm systems that dump freezing rain and snow on the state in winter and cause thunderstorms and showers the rest of the year. If the battle shifts north or south of Illinois for extended periods, we get droughts.

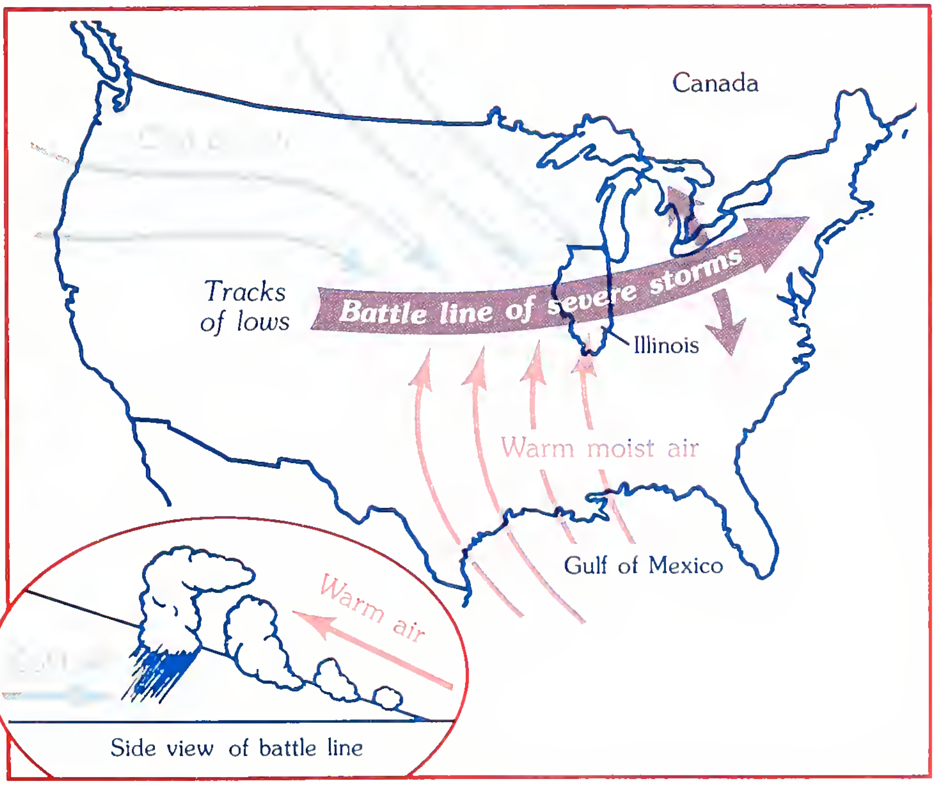


Fig. 1. When warm, moist air from the Gulf of Mexico meets cold, dry air from the northern regions of the continent, a battle of the air masses results. Illinois lies along this battle line, which accounts for severe storms common in the state.

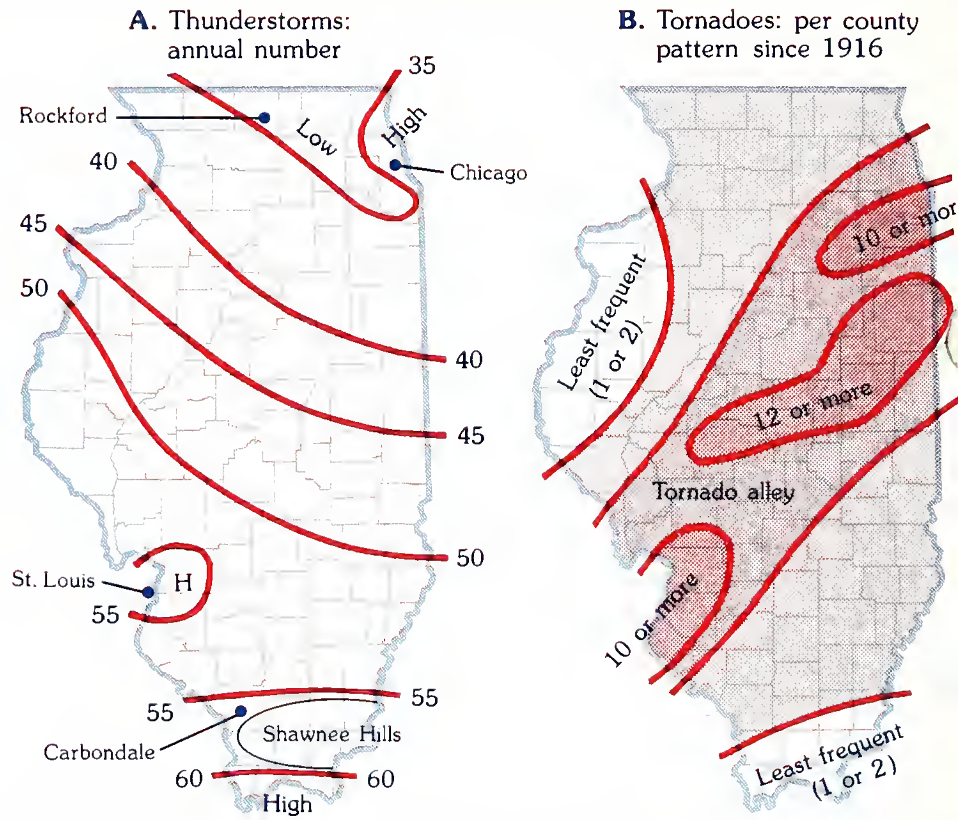


Fig. 2. Many severe storms plague parts of Illinois throughout the course of a year. The frequency of thunderstorms, tornadoes, snowstorms, and freezing rains is indicated on the accompanying maps. Because of wide variations in the weather, atmospheric scientists consider Illinois an ideal place to conduct their research.

Scale

0 50 100 Miles

0 80 160 Kilometers

If it lingers, we get heavy rains. The two battling masses also bring us temperatures ranging from a sticky 100°F (37°C) to a bone chilling −26°F (−32°C).

Local variations. From its northern border to its southern tip, Illinois is almost 400 miles long (645 km). Not surprisingly, then, the climate can vary noticeably from place to place, partly because of topographic and cultural influences. The Shawnee Hills in southern Illinois tend to raise the precipitation in the area by 10 percent and to keep the temperature slightly lower than in the rest of the state during the summer.

Each city in Illinois has its own peculiar climate, which is warmer, less humid, and less windy than the surrounding rural areas. Other facets of the climate are affected as well by two major metropolitan areas, Chicago and St. Louis, Missouri. For example, additional cloudiness and rain are caused by these two cities, which are sources of pollutants and are like giant hills on the terrain. The showers and storms thus generated drift as far as 40 miles (64 km) to the east of the cities before dying.

Jet aircraft are another, relatively recent influence on the cloud cover in Illinois. The state is a national hub for north-south and east-west air traffic. Jets are therefore frequently crisscrossing Illinois, leaving behind them ice particles that contribute to the formation of clouds 6 miles or more (9.7 km) above the earth. Some climatologists are concerned that pollutants from jet aircraft may eventually alter the climate of the Northern Hemisphere.

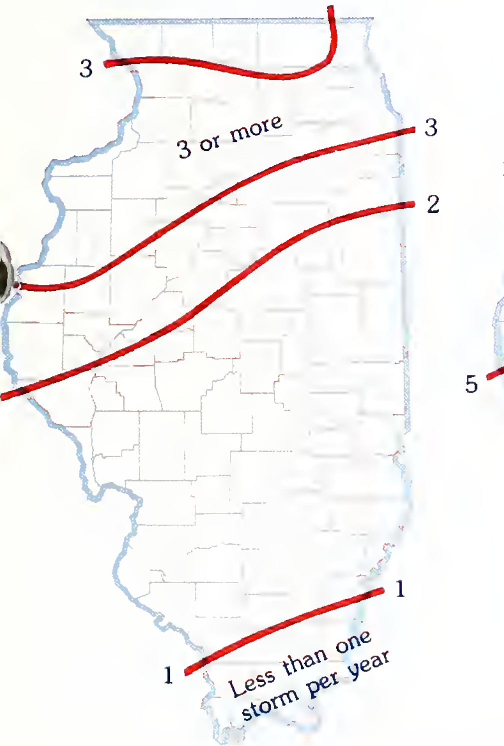
Extremes of weather. The continental climate of Illinois stirs up weather and climatic events that vary on markedly different space-time scales. Humans and the environment are of course strongly affected by these events, which include severe local storms, drought and prolonged wet periods, changes in the climate itself, and alterations brought about by humans.

Heavy local storms are common in Illinois (Fig. 2). Depending on the part of the state, Illinoisans can count on 33 to 62 thunderstorms a year, three days with hail, and thirty days with rains heavy enough to cause local and statewide flooding. Tornadoes whip across the state seven or eight days a year, while strong and often damaging winds occur on another eight days.

The belt of freezing rainstorms that cut across the nation can bring six days of glaze to surfaces in central Illinois during the winter. The northwestern part of the state typically endures three snowstorms that blanket large areas with 6 inches or more (15 cm) of snow each winter. During the winter of 1980 snow piled up to a depth of 40 inches (101 cm) in the Chicago area.

Certain climatic events, although on a par with severe weather, occur on a different time scale. For example, we occasionally have droughts that last from three months to several years. The state was scorched by major droughts in the 1930s and 1950s and recently during 1976–77 and 1980–81. Prolonged wet periods lasting from a single season up to several years are also prevalent.

C. Snowstorms: annual number producing 6 inches or more (15 cm) of snow



D. Freezing rain: annual number of days

The early 1970s and 1980s, especially the fall of 1984, were periods of notably wet conditions.

Climate change is on an even greater time scale than climatic events. One way that the climate can change is in the amount of year-to-year variability. For example, our weather varied relatively little from one year to the next from the middle 1950s to the middle 1970s. Since then, however, we have had great seasonal and annual swings, from record warm to cold winters since 1976 and unusually wet to dry summers since 1980.

A second form of climate change is the gradual shift over several decades to warming or cooling, and to wetter or drier conditions. From 1900 until 1940 Illinois became warmer and drier. Since 1940 the trend has been to a cooler and wetter climate.

Humans and the Illinois climate. The indirect effect that humans have on the atmosphere is noteworthy. Cities, jet aircraft, and the many pollutants released through combustion into the atmosphere affect our climate. We have dirtier air, which influences the amount of incoming and outgoing solar radiation; polluted air, which lowers the quality of our rainfall; cloudier skies because of jet aircraft; and rainier and warmer areas near our largest cities (Fig. 2A).

Meteorologists have attempted to influence the weather directly by cloud seeding to make more rain in Illinois. Although the results are inconclusive at this time, extensive research is in progress at the Illinois State Water Survey. In a project called Precipitation Augmentation for Crops Experiment (PACE), we have defined how added summer rain will help crop production. Scientists are now studying summer clouds with radar and instrumented aircraft to determine which clouds can be made to rain more and how this change can be accomplished. Clearly, the weather can be changed. The question is how much and when.

Stanley A. Changnon, chief, Illinois State Water Survey □

Human Comfort Zones

Michael P. Sherman

Millennia have passed since humans began their struggle to survive the climate in which they live. Trees and caves provided the earliest shelters for family groups. As the population began to multiply and society became more complex, certain individuals were given the responsibility of selecting housing sites and designing the appropriate form. Emerging from the rank of tinkers, these specialists were referred to as master builders.

Early dwellings. The term *master builder* is derived from the Greek word *architekton*: *archi* meaning master and *tekton*, builder. The title was reserved for those most sensitive to form and function; aesthetics was not necessarily a consideration. Master builders had to be knowledgeable about the trees, rocks, hills, valleys, and water in their area. They also needed to be aware of how the sun's position, the wind, and the temperature had a bearing on human comfort.

Master builders looked for the most suitable building sites for developing the final design. Controlling the climate still loomed insurmountable, however. Foremost was their search for locations where farmers could take advantage of the long sunny days needed to produce food for the community. They also looked for places most likely to provide stable temperatures, mild winds, and reliable moisture — a search that is still going on today.

Master builders had to accept the inescapable fact that the perfect building location would never be found. They therefore developed methods for successfully controlling the interior climate of dwellings. Dramatic swings in temperature, wind speed, precipitation, and humidity outside posed major problems for controlling the climate inside.

18th century architecture. By the beginning of the 18th century

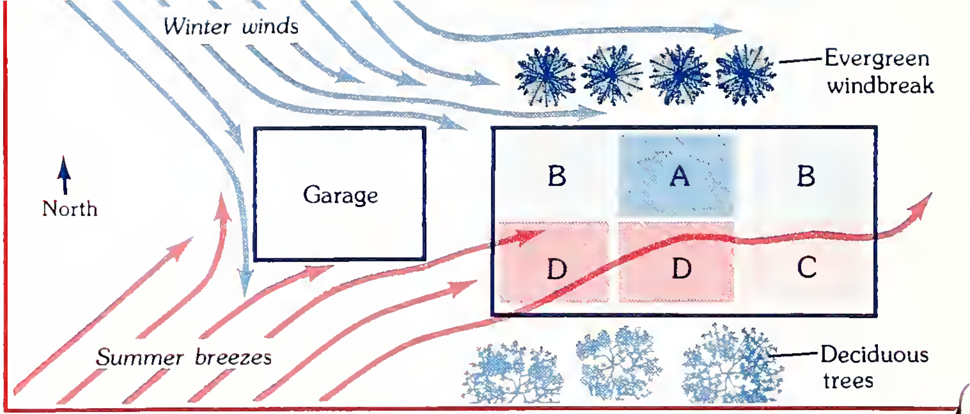
in America, the master builders — now known as architects — quite naturally became regional experts because of the many variations in climate throughout the country. In the middle region of America, or what has become known as the Midwest, the problems were very complex. The swings from breezes to tornadoes, showers to flooding rainstorms, frigid to hot air, long to short days, and dry to humid weather are not unusual. Mildly put, architects had their hands full when trying to outsmart the weather in the Midwest.

Finding it hard enough to fight such a varied climate, architects now had to consider aesthetics and clients' preferences. Clients began choosing the location, the materials, the shape, and the color of their dwellings. Farm homes in particular created a nightmare of complications. Because of the long distances between farms, clustering the houses for protection was impossible.

Choice of building site was dictated by the need to be within sight of the crops and livestock, to be upwind of the barn, and to have the feed yard downstream of the water supply. In short, the farmstead was usually located in the worst possible place for protection from harsh weather. The house was built instead in a convenient place for the owner.

In early designs, most of the family activities took place in one large room. The huge fireplace constructed there was used not only for cooking, but also for warmth on frigid winter nights and the cool spring and fall evenings common in the Midwest. Keeping warm during cold spells was simply a matter of using more wood: massive amounts could keep the cold at bay.

New designs. As construction technology improved and was adopted by architects, the design of homes became even more complicated. Homes began to sprawl and exterior shapes were varied. Forced-air heating systems operating on inexpensive fuel were introduced. The comfort they provided supported the belief that the interior can be environmentally controlled, no matter how peculiar the shape or how



Prototypic house and site plan indicating human comfort zones. This diagram shows house orientation, the direction of winter winds and summer breezes, placement of the garage to act as a wind foil, and tree placement. With this information, the coolest (A) to the warmest (D) places in the house can be identified and matched with appropriate family activities. See chart on facing page.

much energy might be required. People still believed that massive amounts of energy could do the job.

Tossed aside like antiques, regionally sensitive designs gave way to national generic forms. Gone was the front porch, once a bastion against boredom on rainy spring days or steamy summer evenings. Porches were replaced by the all-purpose play room, hermetically sealed from the climate. The potato cellar — also used as summer quarters, a tornado shelter, and clubhouse — was now replaced by the pantry with its refrigerator and extra storage space.

A source of many fond memories, regional designs became a thing of the past for a while. But current trends are returning us to the days when climate changes, both indoors and out, provide interesting variation in our lives. Awnings and ceiling fans are becoming increasingly commonplace, and many people are now using less air conditioning. The energy shortage and higher fuel prices have shocked American architects into evaluating the effects of climate on home design and reviving regional solutions.

Active, passive, or hybrid solar systems are becoming popular (a hybrid system uses some passive and some active elements). Earth berms are also starting to catch on. Modern methods of capturing the abundant energy available in a particular region of the country have created a new emphasis on design. Orientation to the wind, precipitation, and sun are now commonly taken into consideration when a house is built from scratch.

Old homes redesigned. Unfortunately, most homeowners cannot afford the luxury of selling their houses and building new ones. But old homes can be redesigned, thereby transforming them into energy-efficient, regionally sensitive structures. The starting point is an understanding of the activities that take place in the home.

Human comfort zones is the term I use to describe areas of a house that are best suited to certain activities. Let me give a few examples. In cold weather, a room used for reading should be comfortably warm because the occupants generate little of their own body heat while reading. By contrast, a room where the kids are wrestling, and thus generating considerable body heat, can be somewhat cooler.

As another example, painting requires an area with strong natural light for properly mixing the colors. In a room for watching television, however, natural light can cast a glare on the screen and be a nuisance for the viewer. In still another example, kitchens and bathrooms need either natural or ducted ventilation, while storage rooms don't usually need to be ventilated. Regardless of the activity, most people find that a pleasant view from a window gives them a sense of well-being.

A glance at the accompanying chart will help clarify the relationship between the climatic variables and

The purpose of the chart below is to determine how strongly individual family members feel about comfort factors indoors. To identify appropriate rooms for specific activities, fill in the chart, using numbers 0 through 4 (0 = no relationship between the variable and the activity; 4 = a strong relationship). See sample chart at left; this person feels a strong preference for sleeping in a cool room (4) with medium humidity (4) and natural light (4), but does not feel that odor containment (2) or the exterior view (1) are particularly important. The person would be comfortable sleeping in zone A or B in the house diagramed on the facing page.

Sample Chart

0 = No relationship
4 = Strong relationship

Inside climate variables	Family activities: Sleeping	Resting	Bathing	Cooking	Storing food (refrigerator)	Storing food (pantry)	Reading	Watching TV	Playing (active)	Playing (sedentary)	Listening to music	Making music
Temperature hot	1											
warm	3											
cool	4											
Humidity high	0											
medium	4											
low	2											
Light natural	4											
artificial	1											
View interior	3											
exterior	1											
Odor containment	2											
Sound containment	3											

0 = No relationship
4 = Strong relationship

Inside climate variables	Family activities: Sleeping	Resting	Bathing	Cooking	Storing food (refrigerator)	Storing food (pantry)	Reading	Watching TV	Playing (active)	Playing (sedentary)	Listening to music	Making music
Temperature: hot												
warm												
cool												
Humidity: high												
medium												
low												
Light: natural												
artificial												
View: interior												
exterior												
Odor containment												
Sound containment												

the activities pursued. The chart also provides a basis for selecting human comfort zones inside as an adjustment to the the weather outside.

For more exact information, give all household members their own charts to fill out. Surprises may appear when the charts are compared. The results can then be used to assess the possibility of moving certain activities to more appropriate rooms: cooler areas for physically strenuous work or play and warmer areas for reading, studying, or other sedentary occupations.

Information from the charts can be compared with the actual temperature, natural light, and so forth in each area or room of the house and with weather variables outside. Thus a bedroom on the southwest side of a home in the Midwest may be too warm for doing exercises in summer but quite comfortable in winter.

Structurally modifying a house, although more complex than simply relocating activities, is not an impossible job. Interior walls can be shortened or removed so that the air can flow more freely throughout the house for better temperature distribution. Closets and bookcases can be added to northern and northwestern walls as insulation against the prevailing winds. Windows can be built, removed, or altered to accommodate to breezes, natural light, and solar radiation.

The outside of the house can also be modified by adding an enclosed porch, overhangs, shutters, awnings, and carefully placed trees and shrubs. Partial earth berms constructed for insulation around the foundation can lead to dramatic savings.

The home is a versatile environment that can be modified to meet family needs despite the climate. Any changes that improve the interaction between exterior and interior climate can be aesthetically pleasing as well. Given a little thought and planning, a harmonious balance can enhance comfort, bring peace of mind, and save money. Effectively managed, our variable climate can add enjoyment to our lives.

Michael P. Sherman, assistant professor of interior design ☐

Modelling Crop and Weather Interactions

Philip Garcia and Steven E. Hollinger

The effects of weather on crop yields are often painfully obvious to those involved in Illinois agriculture. In 1983, for example, corn yields from individual farms varied from 50 to 200 bushels per acre (2.5 to 9.8 metric tons per hectare), depending upon the planting date. Grain producers are the first to be hit by reduced yields, but the repercussions do not stop there. In a short time, commodity traders, livestock producers, foreign shippers, the federal government, and consumers are also touched by yield fluctuations.

The effects of weather can be separated into two categories: the micro and the macro. Felt by individual corn and soybean producers, the micro effects include bumper yields, crop failures, delays in planting and harvesting, and loss of seed when fields must be replanted after excessive rainfall. Heavy rains can also cause leaching of nitrogen fertilizer or loss of other fertilizers and pesticides through soil erosion.

The macro effects are those that tend to ripple throughout world markets and the economy. But eventually these effects filter back to individual producers through the prices they pay and receive for their goods and through government programs. In many ways, farmers find the macro effects as dramatic as the micro effects.

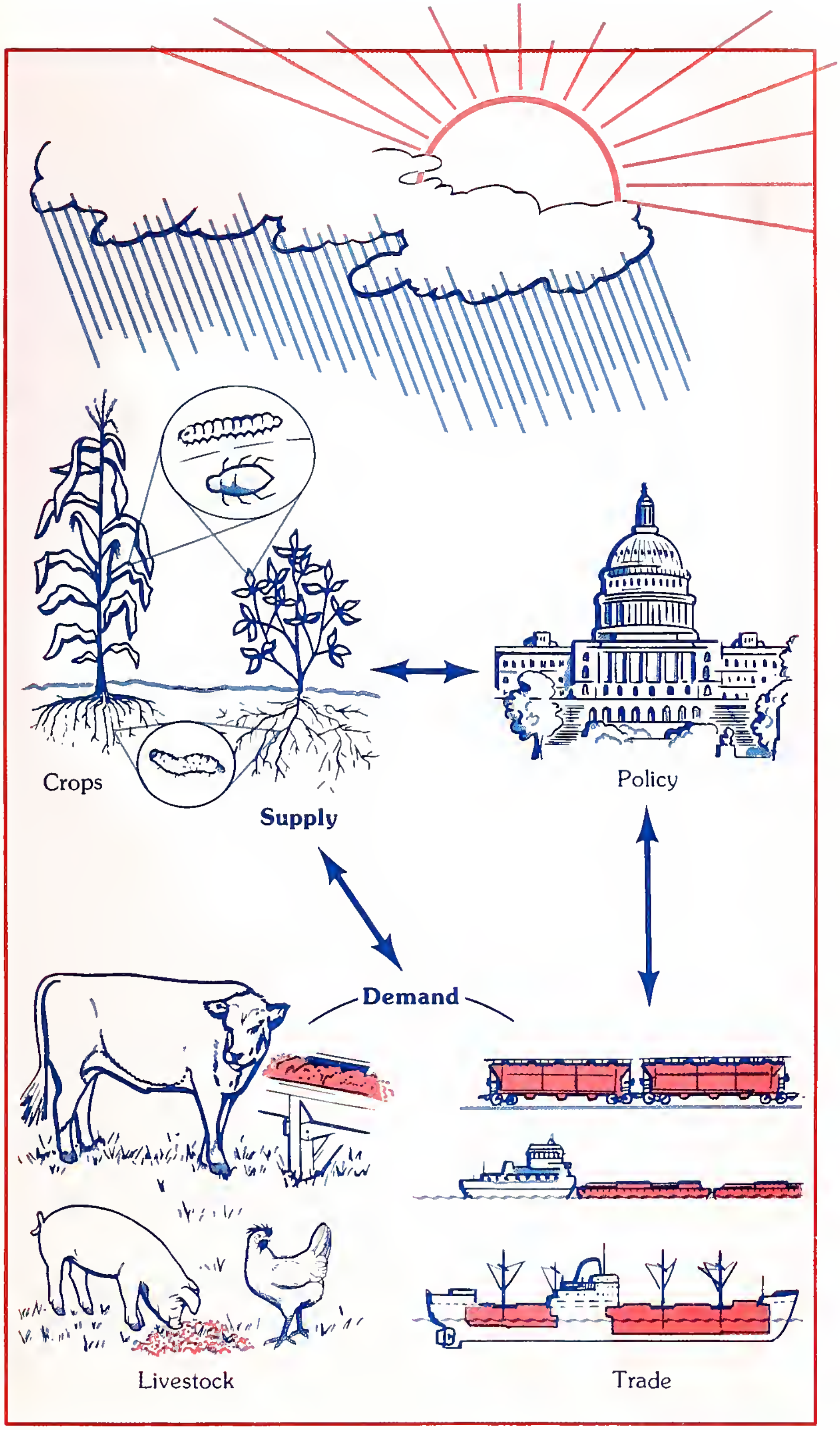
Many producers, economists, politicians, and others feel that agriculture is at the mercy of the weather. They believe that little can be done to manage farm operations to soften the blow of bad weather or use good weather to best advantage. This fatalistic view is now being challenged.

Currently we are working in both the micro and the macro areas to determine how weather interacts with agricultural management and yields. From this work we hope to develop methods to help producers manage their operations efficiently despite varying weather conditions.

Micro effects. At the micro level, we are trying to understand more fully how the agricultural ecological system responds to weather variations. Specifically, we want to know the extent to which day-to-day changes in temperature, solar radiation, and soil moisture affect the corn and soybean crops at different times in the growing season. We are also interested in determining how producers might manage their operations to best advantage, either by increasing or decreasing certain inputs in response to current and anticipated weather.

One study that shed light on several of these questions involved an analysis of corn response to anhydrous ammonia (NH_3-N) in a multiyear experiment. The study entailed examining data from 1975 to 1983 from the agronomy farms on the Urbana-Champaign campus. During these years corn followed corn. We assessed the relationships among maximum yield, NH_3-N fertilization, and the ratio of rainfall to pan evaporation during the rapid vegetative growth stage of corn.

Our findings indicate that when the ratio of rainfall to evaporation is less than 0.6 (not enough water), the response of the corn crop to NH_3-N fertilization decreases. The response also decreases when the ratio is greater than 0.6 because too much water hastens denitrification and leaching.



Weather plays an important part in the agricultural network. Yields on individual farms, and thus supply, are directly affected by the weather, as are aggregate yields over large areas. World weather directly affects foreign demand for U.S. grain, while closer to home the local weather affects the demand for livestock feed and the number of animals fed. The grain trade is influenced by adverse weather, which impedes the movement of grain from farms to the points where it is consumed. Governmental policy also responds to the weather through attempts to balance supply and demand so that the health of the agricultural community can be maintained and American consumers given access to cheap food.

With this type of information, producers should be able to improve the efficiency of their nitrogen fertilizer. Weather information will help them decide how much NH_3-N to apply before planting. Once the weather is forecast for the rapid vegetative stage of growth, farmers can then decide how much additional NH_3-N or other form of nitrogen to apply. Ideally the forecast would be for June 15 to July 15, the stage of rapid growth.

During three of the years evaluated — 1979, 1980, and 1983 — less than 100 pounds of nitrogen per acre (0.1 metric ton per hectare) would have been needed. In fact, no fertilizer would have been necessary in 1980, since each nitrogen increment resulted in a yield reduction.

The ultimate decision about how much NH_3-N to apply is a complex function of the price of grain, the price of the fertilizer, the weather during the stage of rapid vegetative growth, and the anticipated maximum yield when high rates of NH_3-N are applied. Different for each farm, this anticipated yield would depend on soil conditions and the weather throughout the growing season. The best results would be obtained when the weather for the entire growing season is known.

This study was conducted on only one site and on one soil type. Before widespread use of the information is feasible, the effects of soil texture, water-holding characteristics, soil organic matter, and other factors that vary by site will need to be examined. What we have been able to demonstrate so far is that producers can use accurate weather data in making management decisions to optimize the return on each dollar invested.

Macro effects. At the macro level, we are examining the effects of changing weather on production, consumption, and the prices that farmers receive. Until now, relatively small areas such as one or two counties have generally been selected for examining the effect of weather within a short-term framework. The research has not directly linked changing production to national mar-

Photo by Michael P. Sherman

kets for commodities or their end products. The research model we now have permits an assessment over a longer period of time by linking changing weather with production, prices, and the value of the commodity.

The approach involves the development and specification of an econometric model to examine the livestock and feedgrain sectors of U.S. agriculture. The model rests on the assumption that the value of changes in production induced by the weather depends on the interaction between supply and demand. Specific variables such as precipitation and temperature during crucial stages of plant growth are included to analyze how the weather influences feed production, range productivity, and livestock numbers.

Prices at various stages of the marketing system are determined by the interaction of the forces of supply and demand. Feeding back into the production and marketing sectors of the industries, these prices are reflected in subsequent production decisions.

The feed and livestock industries consist of a complex set of relationships that involve biological and economic time lags, differences in the location of production units, and changes in product characteristics. The price of feedgrains is determined by the supply and the demand for them.

Similarly, livestock and meat prices are determined by the supply of livestock and the retail demand for meat. The relationship between output prices for livestock and meat and the producer's input prices for feedgrains constitutes the primary link between the two sectors that influence the production and consumption of feedgrains and livestock. At present, the model explains the production and prices of corn and livestock. It also explains domestic consumption and the export of U.S. corn.

An important step in the analysis is to identify the effects of changing weather on corn yields and on the acreage planted. Using district crop-reporting data, our research attempts to model the effects of precipitation and temperature. In the model, each state is divided into about nine regions. Using this division, we can then specify the varying responses that arise from agronomic and economic differences related to the environment within each region.

Once the model is completed, we will be able to identify the effects of changing weather on farm production, income, and consumer prices for livestock products. Accurate weather forecasts would allow us to project subsequent biological and economic occurrences. Individual farmers might then be able to adjust input and output mixes and thus improve farm revenue.

The model could also be used to determine the value of weather modification. Successful modification can be viewed as a technology for increasing output. Given the structure of farm markets, the total revenue to feedgrain producers drops when the aggregate output is increased. The effects of weather modification will not be uniform, however. Individual producers in a region where the weather is artificially modified have higher yields and hence more to sell. Aggregate market conditions of course determine the price received. However, it is likely that the price reduction for producers in the area will be less than the reduction in per unit costs.

Producers in a region where weather modification is not used will also receive somewhat lower prices. With no additional output, however, these producers are worse off as a result of effective weather modification. In the long run, consumers will come out ahead because of lower prices.

Social implications. These attempts to assess the relationships between accurate weather forecasts on the one hand and the micro and macro effects of the weather on the other hand will ultimately have a bearing on society's well-being. Understanding the relationships is therefore important not only to farmers but to legislators in Springfield and Washington, D.C., as well. The findings derived from the macro model will enable them to make informed decisions related to the farm sector, foreign trade, the agricultural policies of the European Economic Community, and other policy matters.

Clearly, those of us who are investigating the micro and the macro effects of the weather will have to work together closely. Only within this framework can we hope to develop an accurate vision of agriculture and its interaction with the climate, the economy, and the political environment.

Philip Garcia, associate professor of agricultural economics, and Steven E. Hollinger, associate professional scientist, climate and meteorological section, Illinois State Water Survey ☐

The Aphids Are Coming

Michael E. Irwin and L. Keith Hendrie

Although corn leaf aphids are a scourge in Illinois, they don't overwinter here. Each spring they invade the Midwest from southern regions, riding the wind over long distances. After they arrive in the state, they attack field corn, sweet corn, and sorghum.

A study to investigate how the weather influences the migration of agricultural insect pests has been funded for three years by the Illinois Department of Energy and Natural Resources. To date, several innovative research techniques have been developed by a multidisciplinary team of scientists working on the project.

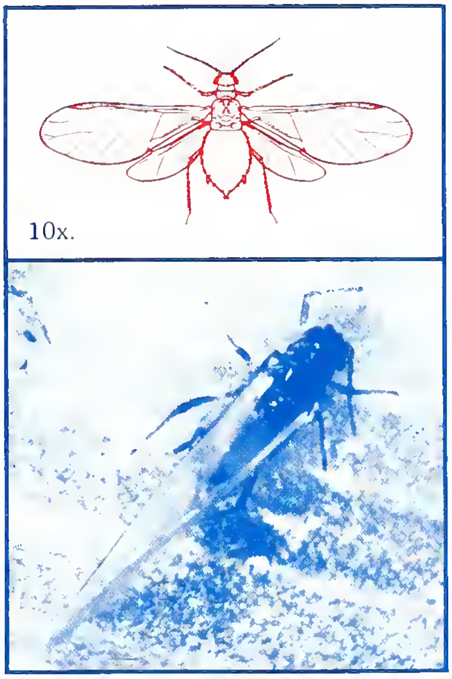
First, genetic markers found in corn leaf aphids are used to determine which southern regions the aphids come from. Second, meteorological analyses of air movement are used to map the pathways followed during migration. Third, the duration of the flight is estimated from fat reserves that aphids draw upon for flight fuel. And fourth, radar is used to detect swarms of migrating aphids and to help characterize them.

Genetic analysis suggested that aphids caught in Illinois in the spring of 1983 probably came from Arkansas and southern Missouri, not from Texas and Oklahoma as previously thought.

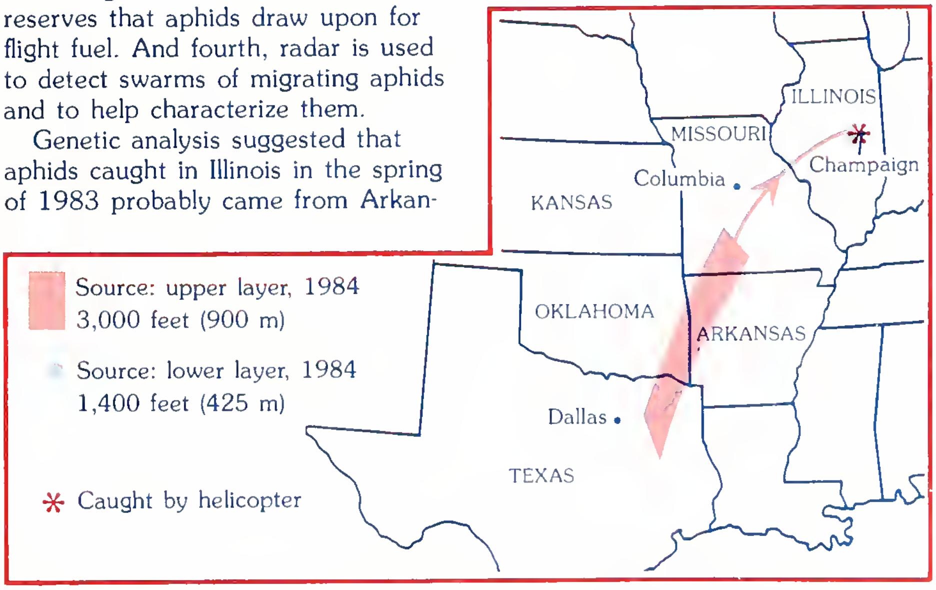
Migratory aphids can now be caught in a specially designed device mounted on a helicopter. The samples can then be used for identification and for genetic and energy analyses. On the morning of August 9, 1984, aphids oriented with the wind were caught in this device during prefrontal conditions near Champaign, Illinois. Weather and radar data for that date were also collected.

Detailed analyses indicated that all of the aphids were travelling in two distinct layers at 1,400 and 3,000 feet (425 and 900 m). Further analyses showed that the two layers came from widely separated regions (see figure). Aphids in the lower layer took off from fields about 50 miles (80 km) west southwest of Champaign early on the morning of August 9. Those in the upper layer had travelled overnight, having left fields between Dallas, Texas, and Columbia, Missouri, the previous day.

Information obtained by these methods will be valuable in predicting future outbreaks of aphids and other migratory pests. Advance weather data and biological information about invading insects could alert agriculturalists to the arrival time and abundance of the insects and hence to potential damage they might cause. Additional funds are being sought to continue this research.



Winged, viviparous female of the corn leaf aphid, *Rhopalosiphum maidis* (Fitch).



Source regions of corn leaf aphids that invaded an area near Champaign, Illinois, on August 9, 1984. The aphids were caught in a specially designed device mounted on a helicopter.

Michael E. Irwin, associate professor of agricultural entomology, College of Agriculture and the Illinois Natural History Survey; L. Keith Hendrie, associate professional scientist, Illinois State Water Survey ☐

Summertime Soda: Relief for Heat-Stressed Animals

Paul C. Harrison

Like all living beings, domestic animals are affected both positively and negatively by their environment. We can define environment as the sum of the biological and physical factors in our surroundings. The long-term meteorological factors in the environment are referred to as climate, and the short-term values of these factors are called weather.

In natural conditions, animals when faced with diverse weather conditions will vary their responses to meet their environmental demands. For example, in a cold environment, animals often seek a warmer climate or simply find shelter from wind, rain, or other related conditions. In a hot environment, animals may seek wind and water. Whatever the weather conditions, the animal will make physiological adjustments to its immediate surroundings (the micro-climate).

Domestic animals, on the other hand, are confined, and producers must take the major responsibility for regulating the animals' microclimate to meet the demands of well-being as well as production. In order to properly design management facilities that meet the biological demands of our domestic animals, we must understand the mechanisms that animals use to adapt to their environment.

Scientists at the University of Illinois are conducting key research in programs that will define the behavioral, immunological, and physiological responses of domestic animals to environmental stimuli. Previous issues of *Illinois Research* have dealt with many of these aspects of our investigation. This article will concentrate on temperature — the environmental variable often referred to as weather — and its relationship to animal responses and management systems. We will also discuss the latest developments in our attempts to alleviate heat stress problems.

Animal responses to hot and cold environments. Most mature domestic animals can survive in a wide range of temperatures. The thermal range for *productivity and well-being*, however, is much smaller, and it is greatly influenced by management.

In cold environments, an animal's productivity is limited mainly by a lack of nutrients. For example, when cattle are mature and fully fed, their production processes are not affected by the cold unless conditions are extremely severe. In general, therefore, cold weather management systems need to protect animals from other environmental variables and to efficiently provide an adequate feed supply.

In hot environments, on the other hand, an animal's needs are difficult to manage. The animal's first response to heat stress is a loss of appetite, which means that the animal will not receive an adequate supply of the nutrients that are essential for its productivity and well-being.

The animal's second response to heat is the loss of body water through evaporation for the purpose of maintaining a constant body temperature. Domestic animals increase evaporative cooling by sweating, panting, or both. For example, horses sweat to cool their bodies, whereas chickens lack sweat glands and must rely on panting for evaporative cooling. Pigs have sweat glands, but these glands do not respond to hot temperatures, and pigs lose body water via the panting process. Most of our other domestic animals rely on *both* the sweating and panting reflexes.

During extended periods of hot weather, the animal sweats and pants excessively and tends to replenish body water too rapidly. Problems related to heat stress could arise as a consequence: rapid water loss causes dehydration, and sudden replenishment creates problems of rehydration.

Sweating results in a decrease in body water and mineral salts (electrolytes). Since sweat contains less salt than the body fluids do, *sweating* animals lose total body salt while, paradoxically, the concentration of body salt increases. This imbalance of body water and salt can lead to serious nerve and muscle problems and even death. Proper management under these circumstances is crucial. Producers can alleviate problems associated with dehydration and rehydration by providing adequate and easily available water and a balanced supply of minerals.

Respiratory alkalosis. In addition to the problems of dehydration and rehydration associated with sweating, the *panting* animal develops another problem — that of acid-base imbalances. As panting increases to cool the body, the animal breathes more rapidly. Through this increased lung ventilation the animal loses an excessive amount of body carbon dioxide (CO_2), and this in turn results in an imbalance called respiratory alkalosis. We have found that respiratory alkalosis disrupts the balance of body ions and water, which affects many conditions — the balance of calcium and other min-

erals, blood flow patterns, and body water distribution.

The thermally induced disruption of body function has a direct effect on the economics of production. For example, respiratory alkalosis induces summertime soft-shelled eggs and affects bone development in chickens; it is associated with heat-induced fetal dwarfism in sheep and possibly affects milk production in various domestic animals. These hot weather production problems cost the animal industry hundreds of millions of dollars each summer.

Feed additives. Many feed additives have been used in attempts to correct the problems created by heat stress, but the results have been mixed and even contradictory. One of the main reasons for the unsatisfactory results is that the animal loses its appetite because of the heat and therefore does not take in a sufficient quantity of the additives.

Even when the animal does consume enough additives, panting and associated problems continue to occur. In fact, feed additives that correct the acid-base imbalance created by respiratory alkalosis generally add to the body's existing deficiency in body carbonate.

On the other hand, those additives that correct for the carbonate (CO_2) deficiency add to the existing alkalotic condition. The effects of normal and hot-temperature panting conditions on the acid-base balance of the body are illustrated in Figure 1. When calcium chloride, which produces hydrogen ions, is digested, it increases the carbonate deficiency, whereas sodium bicarbonate, which corrects the CO_2 deficiency, increases alkalosis.

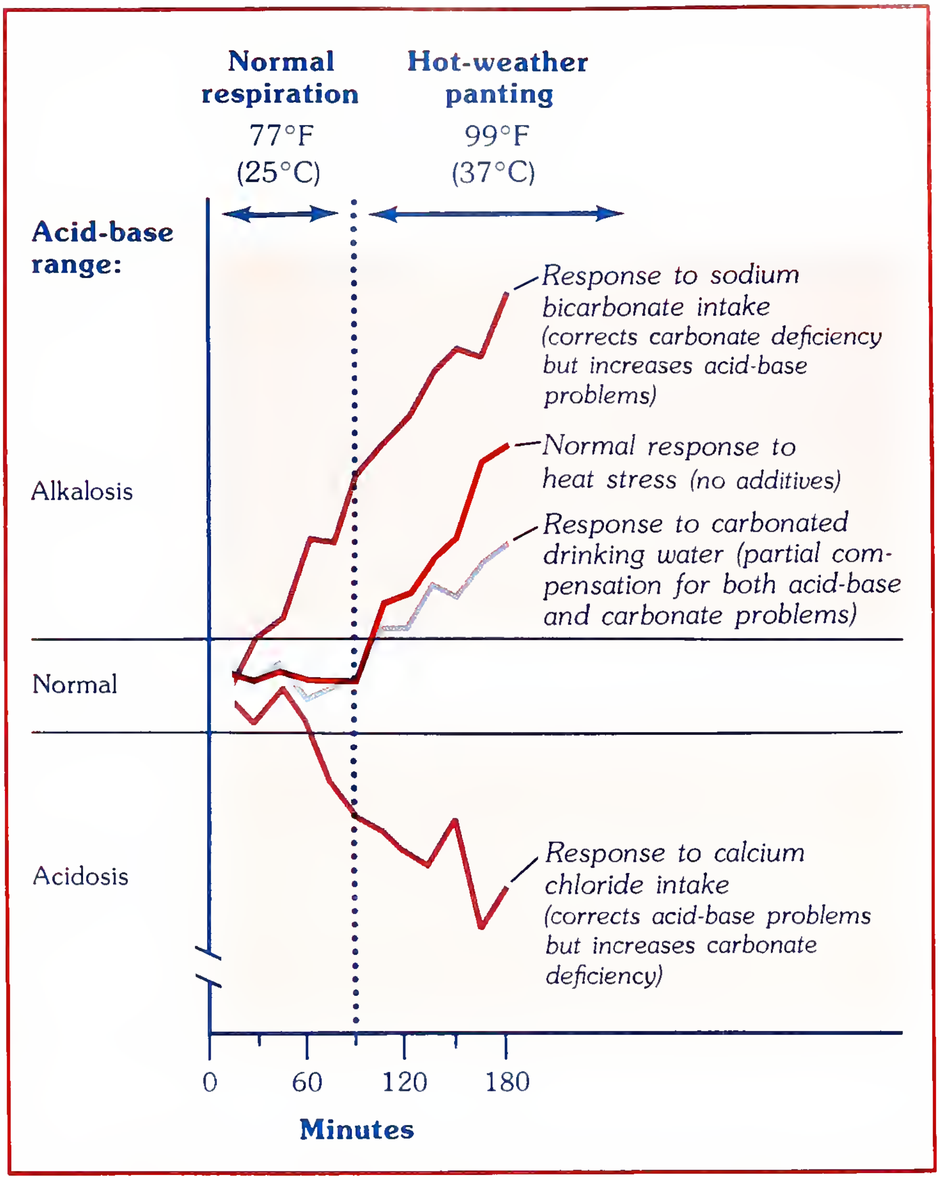


Fig. 1. Change in the acid-base equilibrium of the blood in response to increase in temperature and additives that influence body alkalosis and acidosis.

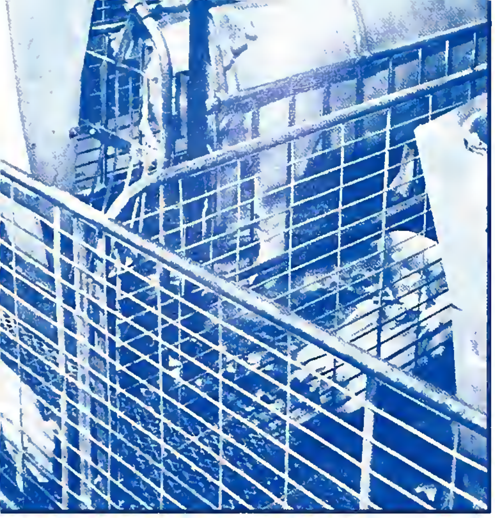
Carbonated drinking water for domestic animals. At the University of Illinois we are developing a management tool that will help alleviate some of the biological and other problems that affect hot weather production.

We know that CO_2 is soluble in water. Because heat-stressed animals drink large amounts of water even when they lose their appetites, we can alleviate the CO_2 deficiency by giving animals carbonated water.

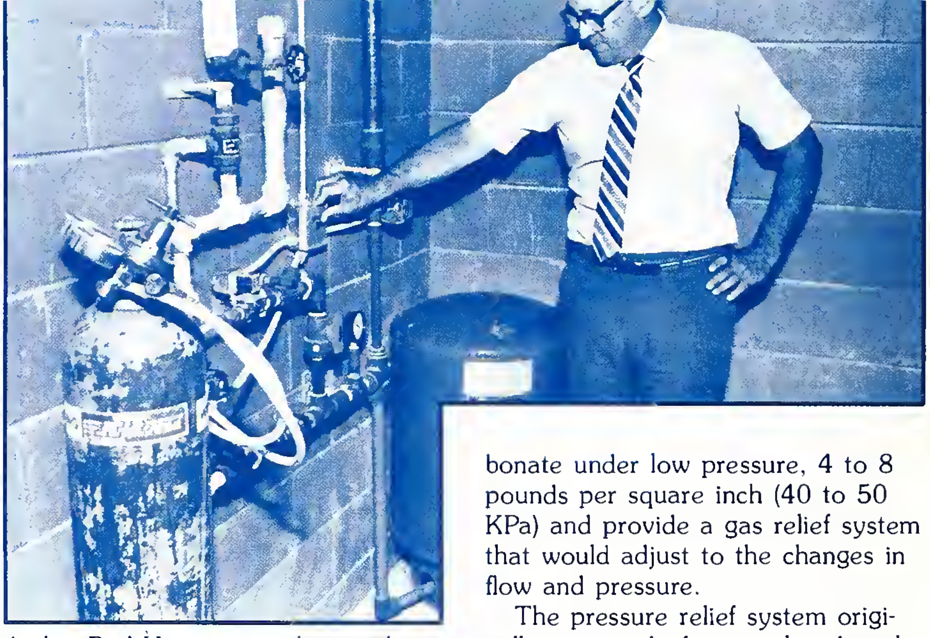
We have developed a relatively inexpensive method for carbonating drinking water for domestic animals (Figure 2). Results from our research indicate that many of the acid-base and water balance problems caused by hot weather can indeed be corrected if the animal drinks carbonated water. Many of the production difficulties related to hot weather can also be alleviated, for example summertime soft-shelled eggs and depressed growth in chickens.

Experiments with the water carbonator shown in Figure 2 are just beginning. Although results from our earlier studies were positive, the water carbonation process was very inefficient.

Our first carbonation system bubbled CO_2 gas directly into the medicator of a poultry watering system. As a consequence, we had to car-



At the Swine Research Center, a sow activates the drinking water system by pushing open a valve. For experimental purposes, two supply lines have been connected to the valve so that the sow may receive carbonated or normal tap water.



Author Paul Harrison switches on the drinking water carbonator at the Swine Research Center.

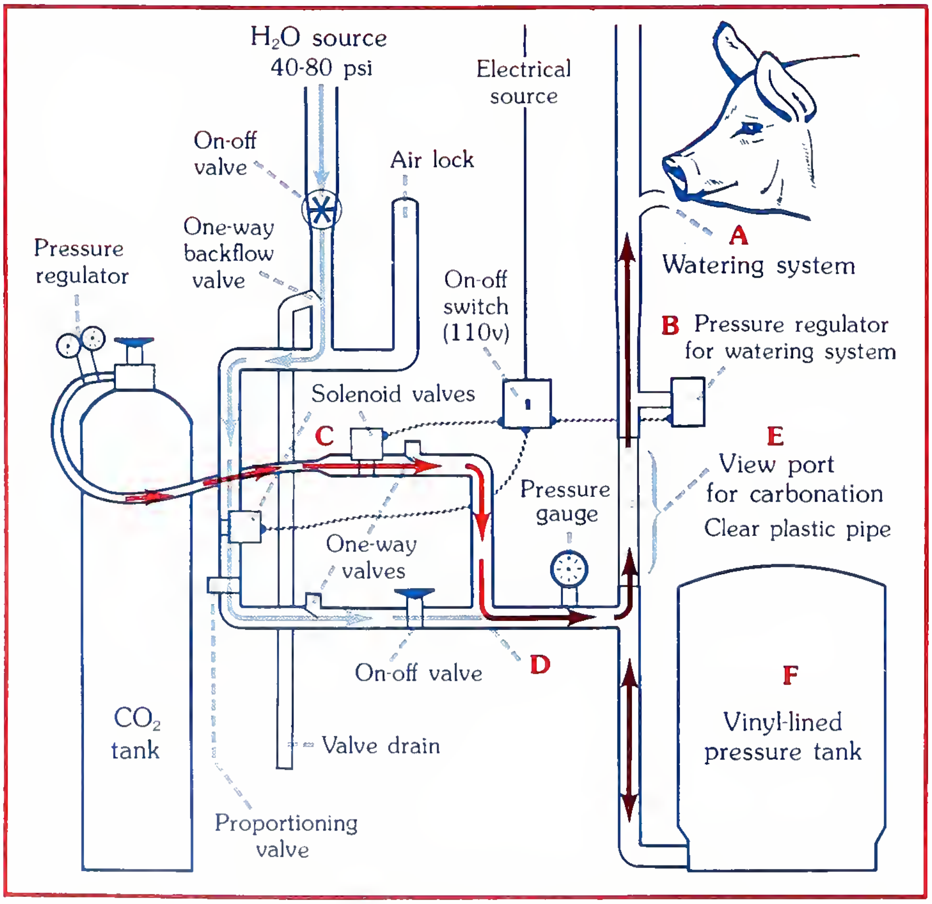


Fig. 2. Schematic representation of a system that adds carbon dioxide to the drinking water of domestic animals. **A.** The animal drinks water by operating a valve. **B.** The decrease in pressure-volume created by the drinking process activates the pressure switch, which opens the solenoid valves. **C.** The solenoid valves simultaneously release water and CO_2 into the system. **D.** The water and CO_2 mix to make carbonated water. **E.** Carbonation is visible through a clear plastic pipe (view port). **F.** A vinyl-lined pressure tank stores excess carbonated water until it is needed. The whole system is compact and can even be portable.

bonate under low pressure, 4 to 8 pounds per square inch (40 to 50 KPa) and provide a gas relief system that would adjust to the changes in flow and pressure.

The pressure relief system originally consisted of a tee placed in the pipe of the watering system. Two feet (about 60 cm) of pipe were used for every pound of pressure. As a consequence, the vertical pipe had to extend through the roof of the building and quite often gave the impression that we were tapped into Old Faithful. However, the system effectively acidified and carbonated the drinking water.

Our new drinking water carbonator increases the acidity and CO_2 content of the water without our having to continually bubble the CO_2 gas. (It's not club soda, but it often fizzes when a valve is first opened.)

For the carbonator to be of real benefit, the entire animal-watering system needs to be converted to a closed system that uses nonmetallic (plastic) pipes. In this system, the drinking valves are operated by the animals. Watering systems of this type are common to most poultry and swine confinement systems. All domestic animals appear to adapt readily to self-operated drinking valves.

Animal management systems can continue to be improved as more and more studies elucidate the relationship between animals and their environment. The end result of these research programs is to create more efficient and effective systems that will ultimately serve human needs through more productive use of domestic animals.

Paul C. Harrison, professor of animal science □

Air Pollution and Crops

Anton G. Endress

Air pollution is not a recent phenomenon. In 1542 the discoverer Rodriguez Cabrillo named California's San Pedro Bay "Bay of the Smokes" because of the large quantities of smoke rising from the Indian fires. In this century, legislation has helped control emissions in highly populated, urban centers. But since air pollutants are spread by the weather, they can and do reach rural as well as urban areas. The effect of air pollution on plants is therefore an important subject of current research.

The rural picture. On clear days, the surface of the earth heats quickly and warms the air next to it. Warm air rises, cold air descends. Under normal conditions, therefore, warm pollutants from smokestacks and combustion engines rise and are carried by the wind to other areas. If the winds die or become light, however, the layer of warm air hangs in one place, creating the condition of thermal inversion. Rising smoke and other pollutants cannot penetrate this layer and spread out beneath it. The worst known toll from a thermal inversion occurred in London in late 1952, when a "black smog" led to 4,000 excess deaths in two weeks.

Catastrophes like those in London rarely occur anymore in the United States and other developed countries. The U.S. Clean Air Act of 1955 and its subsequent amendments established maximum limits, or standards, for some of the major air pollutants. Two standards are applied

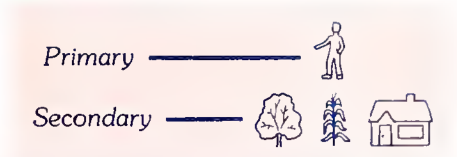


Table 1. ***Air pollutants and some of the plants they affect***

Air pollutant	Sources	Some sensitive plants
Ozone*	Chemical reactions in atmosphere involving sunlight; storm centers; other natural occurrences in upper atmosphere	Potato, radish, green bean, tobacco; ash, Eastern white pine, quaking aspen; lilac, petunia, carnation
Sulfur dioxide*	Fuel combustion; natural gas and petroleum industries; ore smelting and refining processes	Soybean, alfalfa, wheat, oats, green bean; birch; sunflower, aster
Nitrogen oxides*	Exhaust gases of trucks, cars, and tractors; coal, fuel oil, and natural gas combustion; petroleum refining; organic waste incineration	Green bean, lettuce, muskmelon, tobacco; sunflower (nitrogen dioxide)
Hydrogen fluoride	Aluminum industries; refineries; brick plants; steel and phosphate fertilizer manufacturing	Corn; Scotch pine; blueberry; tulip, gladiolus
Particulates*	Cement mills; lime kilns; incinerators; coal, fuel oil, and gasoline combustion	Potentially all plants
Ethylene	Motor vehicles; refuse burning; coal and oil combustion; natural occurrences	Cucumber, tomato; orchid, rose, carnation, Easter lily
Chlorine and hydrogen chloride	Refineries; scrap burning; glass industries; rocket exhaust; accidental spills	Corn, green bean, radish, tomato; white pine, sugar maple; tulip, coleus

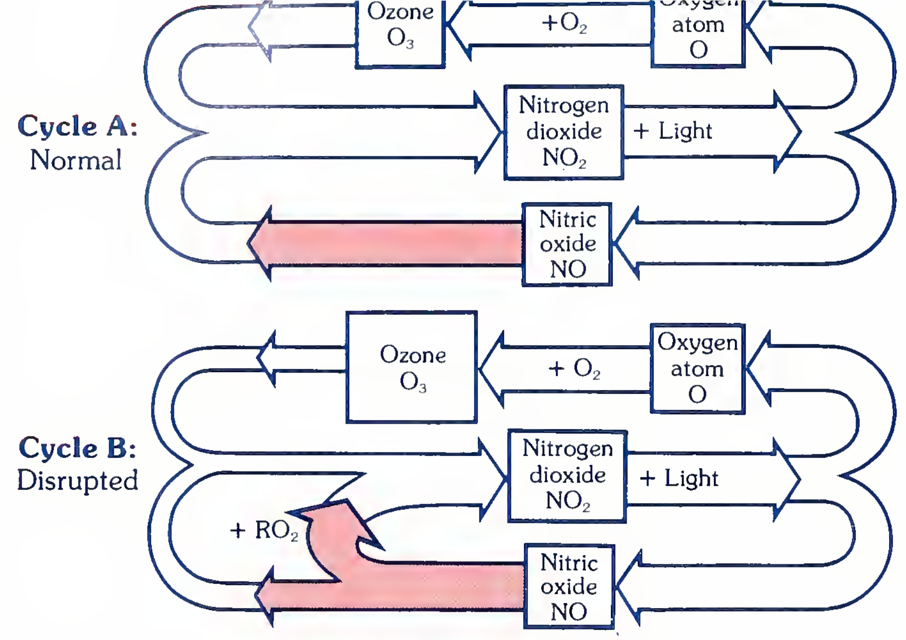
* Secondary standards exist for these air pollutants in the United States. Of the nitrogen oxides, a secondary standard exists for only nitrogen dioxide.

to each pollutant: the *primary standard*, which protects human health, and the *secondary standard*, which protects human welfare — principally vegetation and human structures.

The clean air legislation also established state and federal environmental protection agencies and pollution control boards to monitor pollutant concentrations and enforce the standards. Monitors have been placed in highly populated, urban locations. All of these measures have generally been successful. In Illinois, as in the rest of the United States, data show that concentrations of oxidants have been declining in urban areas.

At the same time, very little is known about the composition and distribution of the air pollutants that affect Illinois's rural and agricultural farming regions. Certainly weather forces carry pollutants from sources such as cities and manufacturing plants to other areas. Since more and more factories are moving away from cities into the countryside, there is reason to believe that rural air pollution is increasing. Meteorological models are currently used to estimate the path and time of arrival of pollutant-containing air masses. But because almost all monitoring networks are located in urban centers, it is difficult to obtain a total picture. The Illinois Environmental Protection Agency operates monitors for ozone and sulfur dioxide in only 21 of the state's 102 counties.

Ozone. One of the major substances of concern is ozone, considered the most important phytotoxic air pollutant in the United States. Ozone is a gas that is produced in the atmosphere by chemical reactions involving sunlight, nitrogen oxides, and hydrocarbons (for sources of these pollutants, see Table 1). It can build up quickly and is not easily



Cycle A. Ozone (O_3), a major air pollutant that affects plants as well as humans, is produced every day by the effect of light on nitrogen dioxide (NO_2) and oxygen (O_2). Under natural conditions, the nitric oxide (NO) that is produced by this reaction combines with the ozone and converts it back again to NO_2 and O_2. In this balanced cycle, therefore, ozone is both produced and broken down, leaving very little remaining in the atmosphere. **Cycle B.** By producing an abundance of hydrocarbons, the burning of fossil fuels disrupts the natural cycle in which ozone is generated and destroyed. Hydrocarbons easily form peroxides (RO_2), which directly convert NO to NO_2, leaving very little NO to react with ozone. Therefore the ozone that is produced is not converted to NO_2 and builds to large concentrations.

Adapted from *Ozone and Other Photochemical Oxidants*, National Academy of Sciences, Washington, D.C., 1977.

depleted. Because sunlight is involved in its formation, ozone reaches high concentrations during periods of high solar radiation, usually between noon and 5:00 p.m.

Plant scientists at the Illinois Natural History Survey, the Department of Agronomy, and the Institute for Environmental Studies (all located at the University of Illinois, Champaign-Urbana campus) are concerned about the impact of air pollutants such as ozone on plants. In studies done on the East Coast, crop losses have occurred at ozone concentrations that are probably typical of Illinois. Since the secondary standard for ozone was relaxed some years ago, there is some concern that the law does not provide adequate protection against this pollutant.

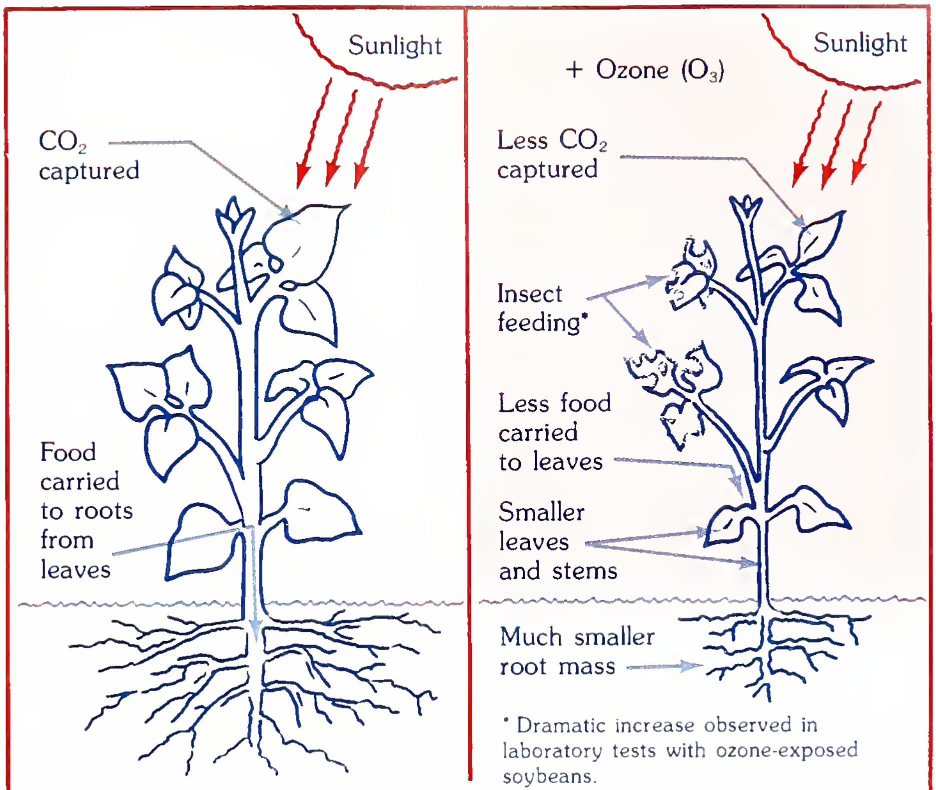
Scientists at the Illinois Natural History Survey have been investigating the effects of ozone, by itself and in combination with sulfur dioxide, on the performance of soybeans. In greenhouse experiments, the variety Corsoy was exposed to concentrations of ozone below the current secondary standard. Two major responses were observed: an initial decline in growth resulting from a reduced ability to perform photosynthesis; and an alteration in the distribution of carbohydrates — the products of photosynthesis — within the plant. Soybean plants exposed to ozone were smaller, grew more slowly, produced fewer and smaller leaves, and had fewer roots. The eventual result was fewer pods and seeds and a lower seed weight. Yield losses were as high as 45 percent at an ozone concentration equal to the legal ozone standard for vegetation. Ozone in combination with sulfur dioxide reduced growth and yields still further.

Seeds produced by Corsoy soybeans grown in the presence of either ozone or sulfur dioxide were also affected. Changes occurred in the relative quantities of oil and protein in the seeds and in the proportion of specific fatty acids in the soybean oil. The seeds also lost minerals and other substances that they normally retain during the early stages of germination. This loss of material could promote fungal or bacterial growth during germination.

Natural History Survey investigators have also shown that plants exposed to ozone are more susceptible to plant-eating insects. In experiments, the Mexican bean beetle and the gypsy moth preferred to feed on soybean or white oak foliage that had been exposed to ozone. Although this preference has not been explained, these studies show that ozone can stimulate feeding by pests — and that vegetation grown in polluted areas may therefore be more susceptible to insect attacks.

The experiments with ozone provide evidence that soybean yield losses are probably occurring in the field from ozone concentrations that do not violate the law. Although stands may appear healthy to the eye, yields and resistance to pests are likely to be reduced. Increased susceptibility to pests means that producers must spend more time and money applying pesticides — and in the process produce more ozone by burning more fuel.

Acid rain. Another problem currently being studied is acid rain. For many years acid rain has been widespread east of the Mississippi River, and more recently it has also been of concern in western states. Natural rain in the Champaign-Urbana area — as measured at the Bondville, Illinois, site by the Illinois State Water Survey — ranges from 3.51 to 6.86, with a median pH of 4.24. Thus Illinois receives rainfall with



Ozone interferes with the basic process of photosynthesis, reducing the plant's ability to capture carbon dioxide (CO_2). Without sufficient food, the plant withholds nutrients first from the roots, retaining as much as possible in the leaves, stems, and flowers. The result is decreased growth, a much smaller root mass, and a reduced ability to produce seeds.

similar properties as rainfall in the most acidic areas of the United States, where the average annual pH is approximately 4.1. A "clean" rain would have a pH of 5.6.

In the acid rain that falls in Illinois, the major anions (negatively charged ions) are $SO_4{-}^2$ (sulfate) and NO_3- (nitrate), and the major cations (positively charged ions) are H+ and NH_3+ (ammonium). The sulfate and nitrate present in this water are derived from sulfur dioxide and nitrogen oxides (for sources of these pollutants, see Table 1), and the ammonium is derived from ammonia, which is produced in great quantities by large feedlots and fertilizers in rural production areas.

The high buffering capacity of the soils in Illinois's farming regions is likely to minimize many of the negative effects of acid rain that seem to be occurring in more sensitive areas of the country. (A soil's buffering capacity is its ability to resist changes in acidity; this capacity is a function of soil composition, especially the concentration of organic matter.) Nevertheless, the effects of acid rain are still not fully understood.

It is postulated that acid rain has both a direct and an indirect effect on plant growth and development; however, no general consensus has been reached, and the reasons for uncertainty are many. At Illinois, an effort is under way to more clearly determine the effect of acid rain on crops. In field experiments conducted by the University of Illinois Department of Agronomy, movable greenhouses are used to automatically cover crops when it rains. Simulated acid rain of six different pH levels, ranging from pH 3.0 (most acidic) to pH 5.6 (no added acid), is then added to the crops. This range is much wider than would occur under natural conditions.

In results from two years, yields of Amsoy soybeans were reduced by roughly 7 percent when the plants were exposed to the most acidic treatment (pH 3.0). For another variety, Williams, no yield reduction or increase was observed from treatment with acid rain. Acid rain as low as pH 3.0 had no significant effects on the yield or growth of either of two corn varieties studied.

Scientists at the Illinois Natural History Survey have also conducted greenhouse studies on acid rain, using rain simulated to contain the ingredients found in "natural" rain. Three pH levels were tested: the lowest was 3.5, representing the most acidic rain recorded for the Champaign-Urbana area, and the highest was 5.5. Soybean plants were exposed every third day over a 130-day growth period and monitored for both nitrogen fixation (the process by which plants incorporate nitrogen from the atmosphere) and photosynthesis. None of the simulated rains inhibited either nitrogen fixation or photosynthesis, and both physiological processes were significantly stimulated under rains of pH 4.5. Seed yield was not affected by any of the rains, even though total biomass was higher for soybeans grown under rains of pH 4.5.

This research suggests that although varieties of some crops may show reduced yields from acid rain, the overall effects on crop production still appear to be quite small. However, further research is needed to explore the interaction of acid rain with other substances. Since air pollutants arise from many sources and are carried and mixed in patterns that are difficult to monitor, there is still much to learn about their precise sources and effects.

Anton G. Endress, associate botanist, Illinois Natural History Survey □

Photo by Michael P. Sherman

Climate Predictions and Illinois Agriculture

Peter J. Lamb and Steven T. Sonka

Even if we know what the summer weather is going to be like, would an Illinois farmer be able to use the information? People who ask this question are not merely passing the time of day. During recent years, large fluctuations in Illinois crop yields have been a direct result of anomalous weather.

In 1979, 1981, and 1982, the weather during the growing season was favorable enough that the state-average record for corn yields was approached or broken — 127 bushels per acre in 1979, 126 bushels in 1981, and 131 bushels in 1982 (7.98, 7.91, and 8.23 metric tons per hectare). In 1980 and 1983, however, much harsher conditions prevailed. Excessively hot and dry weather during pollination and immediately afterwards reduced the state-average yields to 93 bushels per acre in 1980 and to 79 bushels in 1983 (5.84 and 4.96 metric tons per hectare).

Questioning the usefulness of long-range climate predictions is also pertinent because they are becoming increasingly available to the agricultural community. For instance, some are now being offered for sale by private consultants whose meteorological education and expertise vary widely. In this article we will discuss the nature of climate predictions and their current success rate. We will also begin answering the above question.

Short-term climate predictions. Climate predictions are statements of the expected general character of the weather for one or two months, a season, a year, a decade, or even longer. Twenty to thirty days is the shortest period for which climate predictions should be made. The anticipation of atmospheric con-

ditions for briefer time spans deals with weather, not with climate. We are concerned here only with short-term climate prediction (STCP), which deals with a range of twenty days to one year. Compared with longer-term predictions, STCPs can be of much greater use to farmers for making decisions for a given growing season.

Usually made for mean temperature and total precipitation only, STCPs tend to be expressed in extremely qualitative terms such as *above normal*, *near normal*, and *below normal* (Fig. 1). In this context, *normal* is taken as a long-term average, often for the 30-year period between 1951 and 1980. Based on past records, the prediction categories used are designed to have certain probabilities of occurring by chance. For example, the three categories appearing in Figure 1 have an equal such probability of occurrence.

It is important to remember that the prediction for a given time interval, which is known as the prediction period, can be made a month or two before the period begins. The time difference between the date of issuance and the start of the prediction period is called the lead time. While STCPs with long lead times, say three to six months, might be more useful in making agricultural decisions, they are less reliable than those with shorter lead times.

The short-term climate predictions issued by the National Weather Service currently have no lead time. In addition, they often divide the continental United States and southern Canada into only three to six prediction regions (see Fig. 1). Meteorologists say that these STCPs have a coarse spatial resolution. Here in Illinois, the same prediction for temperature and precipitation is generally issued for the entire state. In the case of precipitation in particular, this procedure is not very consistent with previous patterns of climate variation from one part of the state to another.

Weather forecasts versus STCPs. Most people are familiar with weather forecasts, which are issued for only a few days. Compared with STCPs, these forecasts can have lead times of only a day or two, cover a wider range of parameters in a much more quantitative manner, and have a relatively fine spatial resolution. Thus very different forecasts can be made for Rockford in the northern part of the state and Carbondale in the southern part.

With this kind of fine-tuning, forecasters can predict daily high and low temperatures, the probablility of precipitation and its accumulation (especially snow), wind direction and speed, and sky cover. Where appropriate, warnings can be issued for flash floods, blizzards, tornadoes, fog, and other anomalous conditions. It is completely unrealistic to expect that short-term climate predictions will contain such detailed information in the next ten to twenty years.

Accuracy and skill. The reader should also note the distinction between two potentially confusing terms, *accuracy* and *skill*. These terms are commonly used to describe the success rate of short-term climate predictions. *Accuracy* is the absolute difference between the predicted value and what actually occurs. Estimation of an STCP's accuracy is straightforward when the prediction is moderately quantitative, for example, when predicting an average daily maximum temperature of 81° to 86°F (27° to 30°C) for June.

Even when a three-category prediction scheme is used, as in Figure 1, accuracy can be assessed quite simply. The number of correct category predictions is compared with the number of one-category and two-category errors. For example, a one-category error occurs if near normal temperatures were predicted, but they turn out to be above normal. Similarly, a two-category error occurs if below normal temperatures were predicted, but they were actually

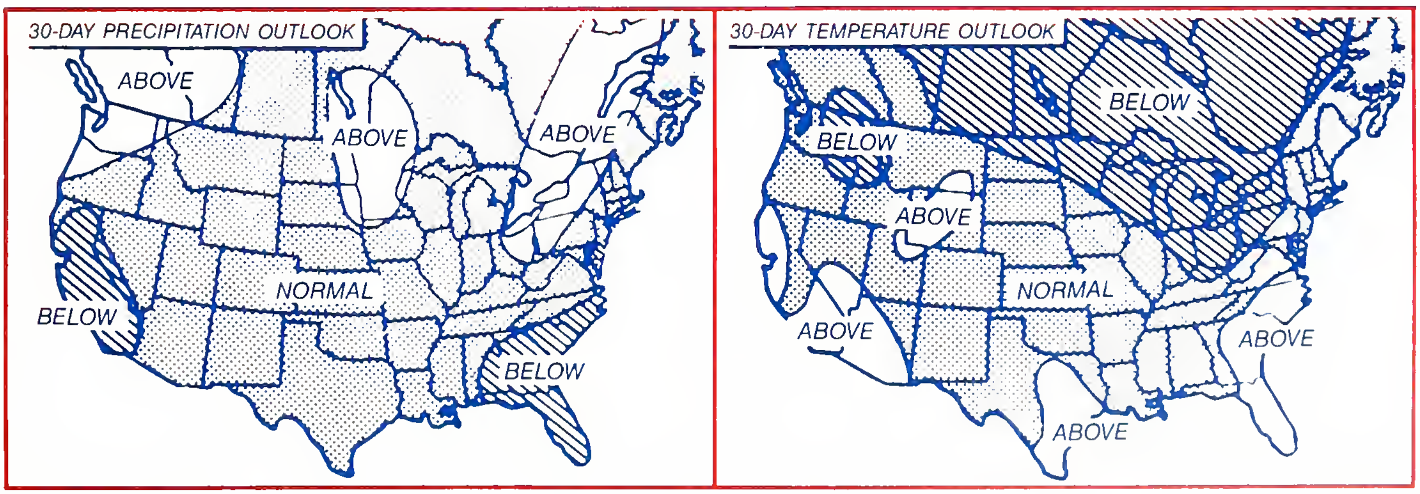


Fig. 1. The National Weather Service's climate prediction for June 15 to July 14, 1985. The prediction was issued on June 14. The maps indicate the precipitation and temperature predictions in extremely qualitative terms (above normal, near normal, and below normal) for relatively large regions of the country. Weather forecasts, on the other hand, are issued for only a few days, are much more quantitative, and pertain to considerably smaller areas.

Source: National Weather Service

above normal. At present it is unclear just how accurate STCPs must be before Illinois agriculture can benefit economically from them.

The term *skill* indicates the extent to which a given method for making predictions is more successful than would be achieved by chance. Skill also refers to the success of a given method compared with that of some other approach that does not require meteorological expertise. An example of the latter is simply predicting that the observed anomaly for one month (for example, above normal temperatures in June) will persist into the next month, or in this case, July.

Unfortunately, STCPs are not very skillful at the moment. A case in point is the National Weather Service (NWS), which typically predicts the correct temperature category only 40 percent of the time. With chance, the predictions would be correct 33 percent of the time. NWS predictions for precipitation are even less skillful, being only slightly more successful than chance.

Whether to buy a climate prediction. People who consider using short-term climate predictions should be highly skeptical of private consultants who claim that their predictions are better than those of the National Weather Service. Before purchasing a prediction from a private consultant, members of the agricultural community should ask several important questions:

- What is the level of the consultant's meteorological education and expertise? Some score very poorly on these criteria.
- How long has the consultant been making STCPs? Even outstanding success during the first year or two can be fortuitous and can rapidly give way to dismal failure. Bear in mind that the National Weather Service has been making predictions since 1947.
- In what manner has the consultant verified his or her predictions? For example, were they published in the press or lodged with an independent person such as a lawyer or a newspaper editor when formulated?
- How accurate and skillful were the predictions and were they better than NWS values?
- What methods were used to produce the predictions?

Answers to this last question should be carefully weighed. STCPs that are based on the alignment of the planets should be viewed with extreme caution. Potential users should also be extremely wary of predictions based on supposed statistical relationships between the Illinois weather during the growing season and meteorological conditions occurring during an earlier time period in China, the Ukraine, the equatorial Pacific, South Africa, or other faraway places.

Some rather exotic and scientifically unproven methods are currently being used by private consultants. In contrast, the STCPs of the National Weather Service are based primarily on the expected wind patterns at 10,000 feet (3,048 m) above the continental United States and adjacent areas.

STCP model. Meteorologists at many universities and government institutions are striving to improve the accuracy and skill of short-term climate predictions for the United States. This work has become one of the focuses of atmospheric science research. Here on the University of Illinois campus, the authors are directing a complementary endeavor to determine which STCP characteristics will be the most useful during the Illinois growing season. The construction of an appropriate economic model is central to this effort.

The research grew out of a pilot study which suggested that the Illinois agricultural system has enough structural flexibility to obtain an economic return from the use of reasonably accurate predictions. In the pilot study we analyzed actual farmer data and weather information for east central Illinois. The excellent growing season of 1979 and the unfavorable one of 1980 were selected for the analysis. According to the results, the corn yield would have been appreciably better had producers been forewarned and increased their fertilizer and planting rates in 1979 and lowered them in 1980.

The model we are currently developing can be used to assess the value of alternative STCP designs and capabilities. It shows how climate fluctuations, production practices, and crop yields are interrelated. In addition, the model will be able to simulate farmers' decision-making processes within the physical and economic constraints on the farm and in an environment of uncertainty. Production practices that could be influenced by STCPs include tillage operations and fertilizer application, both spring and fall; and crop-mix, seed variety, planting rate, and pesticide applications, all in the spring.

We will make quantitative estimates of the economic benefits that farmers might realize if they use the predictions in their management strategies. To do so, we will run the model assuming no predictions, perfect predictions, and a range of imperfect predictions, and then we will compare the findings. Data for past years will be used, for example, for the 1979 to 1983 period discussed in the beginning of this article. In the experiment, the STCP design will be varied for prediction periods, lead times, and meteorological parameters.

From this research we hope to provide concrete information on the best STCP design for Illinois agriculture. We also hope to determine the level of accuracy needed for economic benefits to accrue.

If the price of fossil fuels and raw materials continues to increase, farmers will probably begin using new information as a substitute for these more expensive inputs. As we move to more flexible management strategies, the type of research we are now conducting will be essential.

Peter J. Lamb, head, climate and meteorology section, Illinois State Water Survey, and adjunct associate professor, Department of Atmospheric Sciences; Steven T. Sonka, professor, Department of Agricultural Economics, and adjunct principal scientist, climate and meteorology section, Illinois State Water Survey ☐

Profile of today's farm family

During the 1960s and 1970s the earning ability of farmers and their spouses increased markedly both on and off the farm. The resulting changes in the farm economy have had a significant effect on marriage, fertility, and divorce in farm families.

In 1950 farmers married later than their rural, nonfarm counterparts. More recently, farm men and women have been postponing marriage still longer. Two trends explain the delay, says William Sander of the Department of Family and Consumer Economics. First, farm youths have been going to school longer and choose to delay marriage. Second, the substantial decline in the number of farm families over time makes it more difficult to find a mate from a farm background. In 1980 more than half of the younger wives grew up in a town or city.

Farm families are often thought to be quite large. While true to some extent in the past, Sander says, farm families today are not much larger than other families.

Farm families used to be relatively large because the children contributed significantly to production and were thus an economic asset. Farm wives tended to stay at home and could therefore care for a large brood. But agriculture today is capital intensive; fewer children are needed to help run the farm. Dairy farms may be an exception because the children can help with the cows.

Because many farm wives are beginning to work off the farm, the cost of staying at home to raise children is now rather steep. In a very real sense, farm children have become expensive to raise, particularly when the mother's time is considered. Thus family size has declined.

Although still below the nonfarm rate, the divorce rate in the farm sector has risen during the past decade. One important reason for the trend is that farm wives, especially those who hold outside jobs, are better able to support themselves.

For a number of years their nonfarm income has been increasing steadily. Nevertheless, it is still lower than that of women in the nonfarm sector. Often handicapped by substantial distances between farm and city, farm women gain less work experience in the nonfarm economy. This lack of economic flexibility helps keep the divorce rate relatively low among farm families, Sander says.

Salmonella — unkind but common

The word *salmonella* has been used often enough lately in the news to be easily recognized by the general public, particularly in Illinois. Some people might think that salmonella food poisoning is a new and exotic affliction, but it has probably been around at least as long as humans. The organism was first isolated in the late 19th century by D. E. Salmon, after whom it was named.

The onset of the illness is rather abrupt, occurring roughly 12 hours, but sometimes up to 24 hours, after eating. Lasting about two days, the symptoms usually include a low-grade fever, some vomiting, abdominal pain, nausea, and diarrhea.

Fatalities are rare; the most susceptible groups are infants, the infirm, and the aged. Many people do not even feel sick enough to seek medical attention. Although an estimated one million people are afflicted with salmonella food poisoning each year, the common cold and hangovers are still the primary cause of absenteeism, says food scientist Lloyd Witter.

Salmonella infections are extremely widespread in animals. Despite serious efforts by the poultry industry, chickens, eggs, and egg products remain the most common source of salmonellae organisms in foods. Until a few months ago, pasteurized milk was considered a rare and unlikely source. Experts believe it will remain so in the future.

The organisms are rather easily destroyed by heat, and pasteurization eliminates even large initial populations. They are also rather quickly killed by low pH and by the freezing process. Once having withstood freezing, however, the bacteria can survive for long periods in a frozen condition. Normal refrigeration holds them in check.

The minimal infective dose varies markedly with the susceptibility of the host and with the particular strain. Each person afflicted in the outbreak last spring probably ingested no less than 500,000 organisms. Salmonellosis probably won't be associated with milk in the future, Witter says, given the sensitivity of the organisms to pasteurization, their inability to grow when refrigerated, and the large number required for an infective dose.

So what happened? No one knows. Investigators located a valve that may have been the culprit, but it is unlikely. Because the organism is no longer around, it's like trying to find out what someone had for dinner two weeks ago by analyzing dishes that have been washed many times since then.

The problem has now passed from science to politics and legal opportunism, Witter says. One thing is highly probable, however: milk will be safe to drink for a long time to come.

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Publications

More About the Weather

The publications listed here provide additional information about topics discussed in this issue of *Illinois Research*. Copies may be obtained from local libraries, through interlibrary loan, or from the publisher.

Climate and Weather. Hermann Flohn. 1969. New York: McGraw-Hill, World University Library. 253 pages.

Climates of Hunger. Reid A. Bryson and Thomas J. Murray. 1977. Madison: University of Wisconsin Press. 171 pages.

Fundamentals of Meteorology. Louis J. Battan. 1979. Englewood Cliffs: Prentice-Hall. 321 pages.

Illinois Research

Fall 1985

Mechanization in agriculture

Illinois Research

Agricultural Experiment Station
Fall 1985

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 27, Number 4

The Changing Agricultural Scene

When the early settlers came westward to Illinois a century and a half ago, they brought with them the basic tools of agricultural production. Despite the Industrial Revolution, the implements available at that time were very similar in design to those used by early Egyptian farmers. Although the land to which the settlers came held much promise, agricultural work in those days was hard.

The first challenge for the settlers breaking the prairie lands was to replace hand tools with horse-drawn machines. Farmers soon realized that a human laborer, even in good physical condition, could expend only about one-eighth of a horsepower of energy (0.1 kW) in a full work day. The shift to animal power was a great step forward, but there were limitations, both in the size of machinery and the speed with which farm operations could be performed. Since then, rapidly developing technology has greatly changed the agricultural scene.

Some of the conditions under which the current level of mechanization was achieved no longer exist, and questions are sometimes raised about the future of mechanization. In California, for example, action has been initiated to prohibit the spending of public funds on research promoting mechanization that may replace human beings with machines.

Although mechanization may displace human labor, it also provides opportunities for human participation at a different level. It is therefore imperative that agricultural research on mechanization continue. This research — in which the University of Illinois is a leader — refers to the process of applying technology to the production, harvesting, and utilization of agricultural products. Already, mechanization has reduced the drudgery of the agricultural worker and increased outputs. Machines have not only saved muscle power, they have also freed human beings from routine decision-making and tedious procedures.

The benefits of mechanization have accrued not only to large-scale operations, but also to small-scale farming. Mechanization is essential to all phases of agricultural production. In fact, the present-day family farm is possible only because high-capacity power units and machines are available to all farms. The part-time farm operation depends heavily upon a supply of good used equipment that is reliable and has the appropriate capacity.

By the end of this decade, advanced electronic and mechanical automation, computer data bank systems, and artificial intelligence will become commonplace. The direction of agricultural research will no doubt be influenced by several factors — the declining population rate, the high cost of petroleum fuels, overproduction, and the changing demands of capital and labor. The major thrust of that research, however, must be to continue providing the technology required to feed our population. For us to remain leaders in food production, it is essential that we reinforce our commitment to mechanizing agriculture in the United States.

Roger R. Yoerger, professor emeritus and former head, Department of Agricultural Engineering

The Cover

See page 2

"At a time unlike any in the past, we must envision the future."

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Illinois Research

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Agricultural Mechanization

The Cover

Ever since the Industrial Revolution, the concept of mechanization has dominated human consciousness, particularly in the western world. "The Age of Machinery," as Thomas Carlyle called it in 1829, continues to pervade our lives and is fast propelling us into the age of computers.

The steam engine was the most visible symbol of the age of machinery, providing power for railroads, textile mills, and farm machines. Our cover for this issue depicts one such machine — the prairie plow. Adapted from an engraving in Alexis Everett Frye's *Advanced Geography* (1895), the picture has special meaning: it represents the dramatic entry of mechanization into the agrarian world, of a force that changed the rural landscape forever. The phenomenon of agricultural mechanization has long captured the minds of American writers and painters. "The sudden appearance of the machine in the garden is an arresting, endlessly evocative image," says scholar Leo Marx in his book, *The Machine in the Garden*.

Mechanization has been the source of profound elation because it symbolizes human control over the environment, but it has also been the source of deep anguish. The sense of closeness to the soil and to the natural world is vanishing, for mechanization restricts human contact with the land. The sights, the smells, the sounds that uplift the human spirit are often lost in the roar of engines and the rattle of chains, pulleys, and gears.

Yet, despite nostalgia for the nonmechanized past and ambivalence towards mechanization, one cannot deny that machines have improved human life in many ways. There is also no denying Leo Marx's observation that "it is technology, indeed, that is creating the new garden of the world."

Mechanization and Beyond: Reaping the Bounty

Donnell R. Hunt

Over the past century, the mechanization of American agriculture has dramatically changed farmers' lives. The most obvious benefit of this mechanization, especially with the advent of the tractor, has been freedom from drudgery. "The man with a tractor," as essayist Morrow Mayo called the farmer in 1938, was transformed from a "humble tiller of the soil" into "an operator." The tractor had freed farmers from long hours of hard physical labor, and it continues to symbolize hope for farmers in developing countries.

But mechanization does not and cannot proceed only on a farmer's desire for less drudgery. The parallel development of a given set of conditions within a nation affects the total process.

The climate for mechanization. In 1953 Eugene McKibben, USDA Director of Agricultural Engineering Research, analyzed the evolution of mechanization, listing the "combination of favorable circumstances" under which this process had occurred in the United States. McKibben's analysis is instructive even today. Some of the circumstances he refers to recall significant history; others are relevant for predicting the course that engineering must follow if it is to continue contributing to a better agriculture, both in the United States and in developing countries. According to McKibben, the parallel development of the following circumstances was conducive to mechanization in the United States.

- Political: a stable, equitable government over a large area, a government that favored initiative and free enterprise, raised no internal trade barriers, and supported compulsory education.
- Social: the absence of a serf or peasant class, a desire to increase production to benefit more people, and a willingness to accept change as each generation moved farther west to pioneer a new frontier.
- Geographic: the abundance of clear, level lands, well suited to mechanization.
- Demographic: a rapidly increasing population that produced expanding markets and, at the same time, created chronic shortages of agricultural labor. A rapidly expanding industrial development absorbed the labor released by farm mechanization and supplied many of the elements needed to perfect and produce new machines.
- Historic: labor shortages resulting from three major wars. These shortages spurred the adoption of reapers in the Civil War, tractors in World War I, and combines and cotton pickers in World War II.
- Transportation: a network of railways and, later, truck highways that enabled large shipments of farm products to reach remote, concentrated markets.
- Research-related: advancements in the biological sciences that produced plant varieties better suited to mechanical harvesting — hybrid corn, shatterproof small grains, stormproof cotton, and crops with uniform growth.
- Technological: improvements in manufacturing technology and methods that furthered agricultural mechanization; for example, inexpensive methods for producing steel, gas and electric arc welding, precision ma-

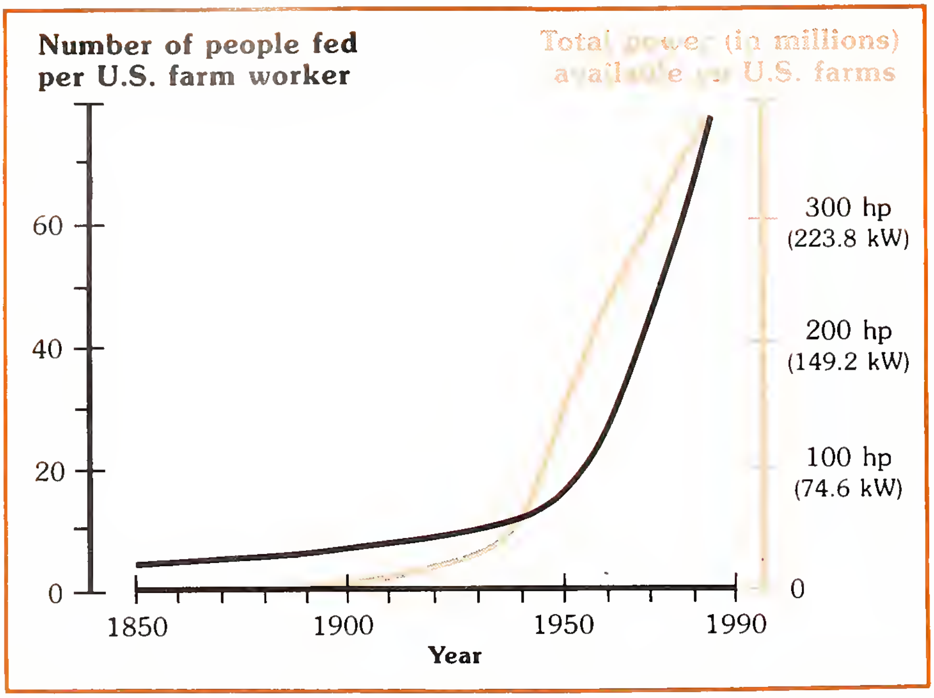


Fig. 1. Agricultural productivity from 1850 to 1984. The number of people fed per agricultural worker increases rapidly from 1960 on, suggesting a strong correlation between the productivity of the agricultural worker and the availability of power.
Adapted from U.S. Census Data.

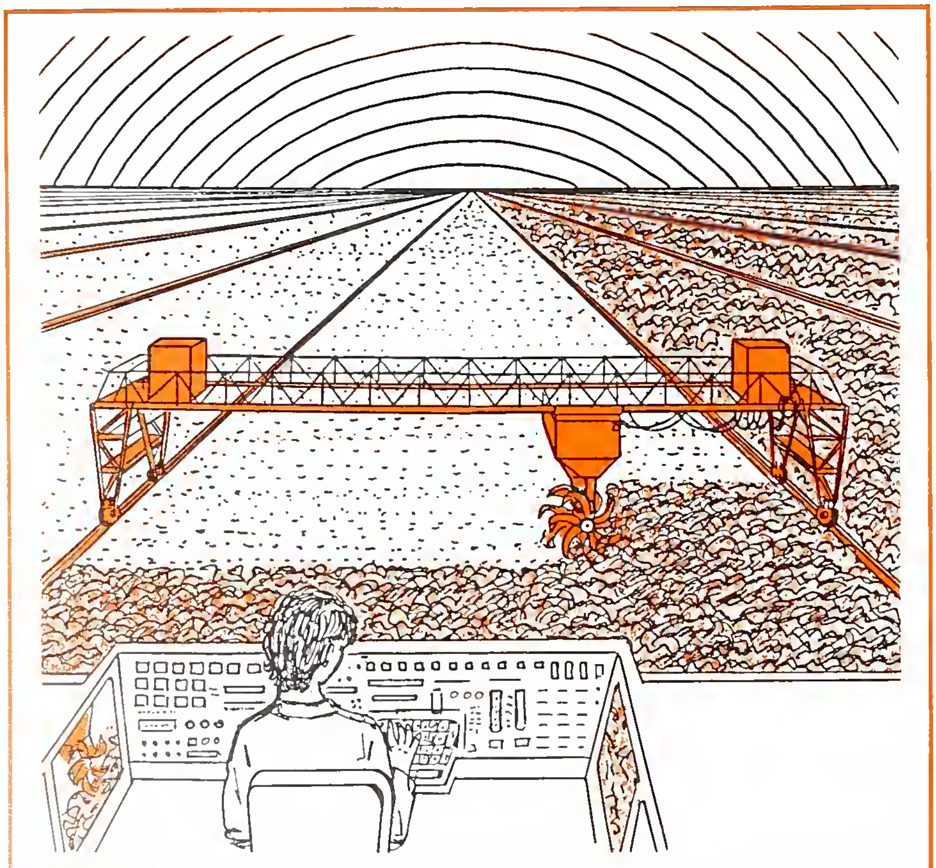


Fig. 2. A glimpse of the future. Production agriculture will eventually be automated so that most machines are controlled by computers. One operator in a control tower will be able to regulate several production activities electronically.

chine tools, and well-managed assembly lines. Specifically, McKibben referred to these technological advances: the evolution of the internal combustion engine along with the coordinate development of fuels and lubricants; simple, efficient electric motors, high-quality antifriction bearings, pressure-gun lubrication, seals for transmissions and exposed shafts; pneumatic tires; and hydraulic control systems.

- Chemical: the development of a progressive agricultural chemical industry that supplied fertilizers, pesticides, growth regulators, and fruit-retention chemicals and thus permitted large-scale mechanized agriculture.
- Processing: improved processing plants, such as those for cotton and sugar, that helped make mechanical harvesting more acceptable.

Productivity and power. The preceding summary is relevant even today. In 1953, the miracle McKibben described was just beginning. Since then, technology has accelerated smoothly so that fewer and fewer farm workers are supplying the needs of an ever-growing population. However, despite the explosion of productivity that began in 1960, it is inconceivable that the trend will continue to the point where one farmer will feed the world.

It is generally inferred that the number of people fed per agricultural worker increased as mechanization expanded on the farm. If this were the case, then the number of people fed per agricultural worker should have increased much more rapidly than it did before 1960 (Fig. 1). Strictly speaking, the replacement of hand methods by mechanical ones was completed many years ago for grain and forage harvesting; it is almost complete now in animal production and in the harvesting of fruit and vegetables. Clearly, the figure indicates that the sharp rise in productivity coincides with a dramatic increase in the amount of power available to the farmer.

The amount of power available for agriculture is second only to that available for automobile and truck transportation and for electric power

generators. Today, each farm worker has about 85 horsepower (63 kW) available for use. (The total amount of power available, however, is diminishing, which implies that there is a practical limit to the productivity of the agricultural worker.)

Agricultural industries. Productivity is also affected by the changes in industry. In 1850, farmers used to present their products to consumers in a raw state. Since then, many processing, marketing, and distribution businesses have arisen that support agriculture. All of these agribusinesses, as well as the individuals employed in education, research, and extension, are as much a part of agriculture as is the production worker. If we add the number of workers in these related segments of agriculture to the number of farm workers, we find that the agricultural industry work force totals 22 to 23 million. The true ratio, then, of people fed per person involved in supplying the food is almost 5 to 1 — about the same ratio as in 1850! Clearly the potential still exists to narrow the gap further by increasing productivity through greater mechanization.

Automation. Perhaps now is the time to cease speaking of agricultural *mechanization* and to use instead the term agricultural *automation*. Where mechanization replaces labor with machines, automation replaces human control of those machines with computers. Like other product industries, agriculture should invest more in automated production, both on and off the farm — in low-cost computers and process controllers. As the price of electronic goods decreases, computers and related equipment will be within the reach of the small farmer. Prudent investments along with good management principles will allow the small farmer to compete effectively in the agricultural market. Ultimately, the benefits of such investments will include conservation of energy, more uniform products of higher quality, and lower costs.

If automation continues to proceed as rapidly as it is currently proceeding, the production agriculture scene will be like that depicted in Figure 2. Solar energy, for example, will be combined with other elements to produce food. In fact, the location of future product processing plants will be determined by considerations such as energy and resource conservation, environmental pollution, and the feasibility of recycling wastes.

Despite the rapid changes that have taken place since 1953, many of McKibben's "favorable circumstances" are still relevant today. They give us insight and can shape our decisions in agriculture. We can learn from those circumstances even as we move beyond them. The future well-being of the United States will depend on rational planning, technological development, abundant power, and the economic application of the principles of automation. It will not depend just on the production of raw products but on a whole interrelated system that supplies the nation with its food.

Donnell R. Hunt, professor of agricultural engineering □

From Industry to Academia

Roscoe L. Pershing

As the new head of the Department of Agricultural Engineering, I am often asked to compare the industrial world with the academic. Although my experience in academia is rather limited — a few months as opposed to 19 years with Deere & Company — I can identify some striking similarities and differences. It is important to remember, though, that my experiences are specific to a major industrial firm and a large state university.

Similarities. Both the University of Illinois and Deere & Company are deeply committed to quality and excellence in their respective products. Both administer a mountain of paperwork! They are faced with similar challenges when dealing with change, employing interdisciplinary teams, and performing a diversity of tasks. Surprising? To most people, probably yes. They might not suspect that the administrative overhead is so great in industry and that the research may sometimes be comparable. In both respects, therefore, the two sectors are very similar. But yes, there are some differences.

Differences. The tasks I am managing now as department head are more diverse than those I managed at Deere. Chiefly, the reasons for the diversity are as follows:

First, there is an obvious organizational difference between industry and the university. At the latter, departments are not automatically provided with a personnel section. Consequently, the head must deal with seemingly hundreds of chores, which though essential, could easily be performed by someone else. For example, responses to public inquiries and tasks related to authorizing keys, part-time student wages, and salary appointments are generally handled in a university by a department head. Sometimes these responsibilities are delegated in part to an administrative assistant or business manager. The addition of such a person depends to a large extent on the head's initiative, as well as on the budget.

Second, the funding and budgeting processes at the university are very

different from those in industry. There are at least three different fiscal years involved in the university; and within a large department one must manage over one hundred accounts, each with many subaccounts. People are often paid out of two or more accounts from different fiscal years. It seems as if no one individual in the university quite understands this system or is able to answer all the questions about it. In some cases, one's computerized transaction and balance statements arrive too late to be really helpful.

Industry, on the other hand, has a budget office that supplies timely information. Users are provided with meaningful summary printouts of account balances that compare these balances with projections for a particular time, and there is only one fiscal year.

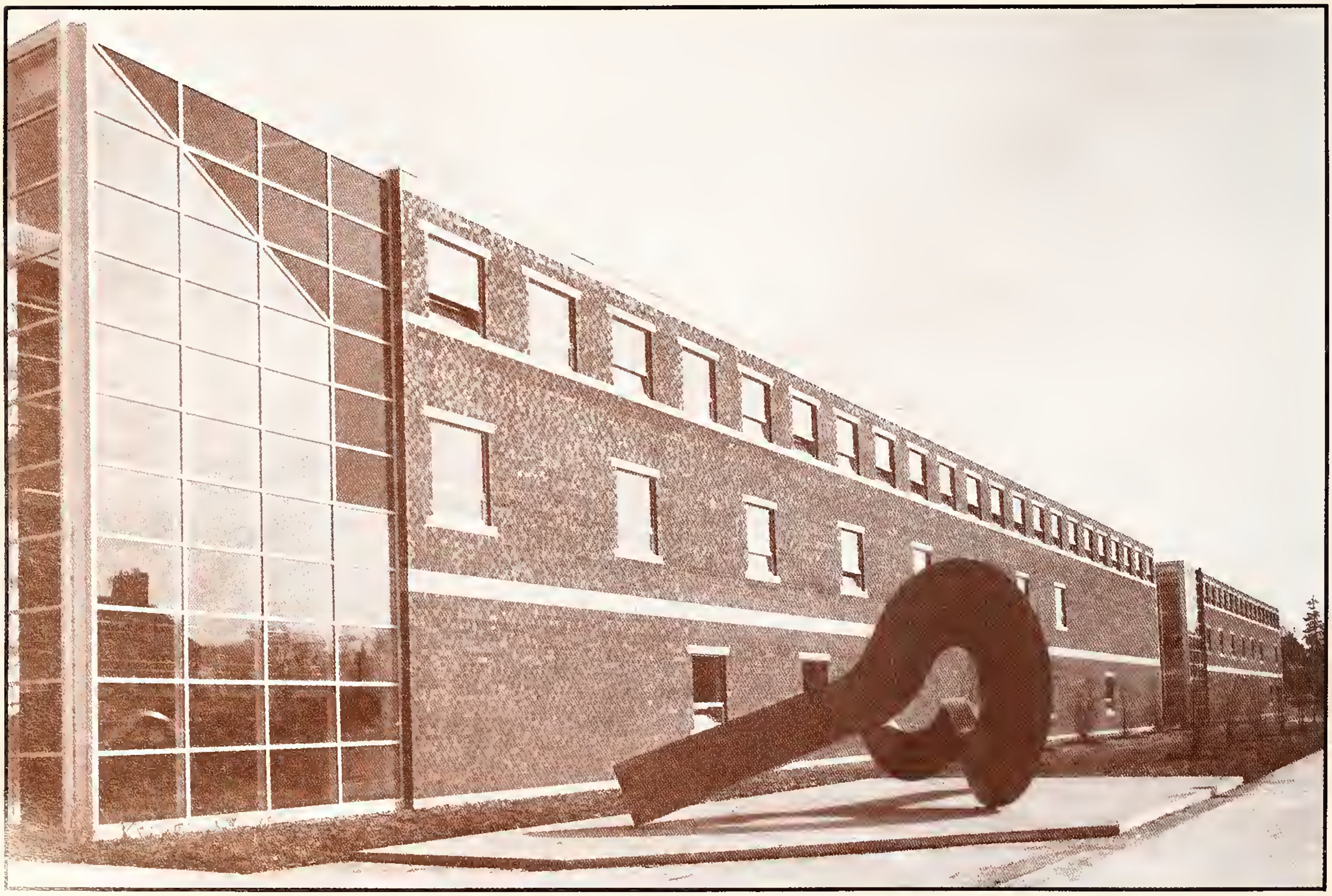
Third, the scope of work is intrinsically wider at the university and usually encompasses teaching, research, and extension programs. In industry, jobs of equivalent stature focus more on just one activity, such as research, marketing, or development.

A fourth and major difference is in the freedom to act. Here the university shines! Large industries have a more strict chain of command, which often inhibits individual initiative. The university, on the other hand, thrives on "shakers and movers" and fosters individual initiative. In administrative matters, too, one has greater freedom.

In general, more stringent deadlines are imposed in industry. The pace, however, can be fast or slow at both the university and industry even though the latter thrives on a quicker pace because of competition. Highly motivated individuals, however, will generate their own speed wherever they work; they may find, surprisingly, that in academia a faster tempo results because of the immense number of tasks that must be accomplished.

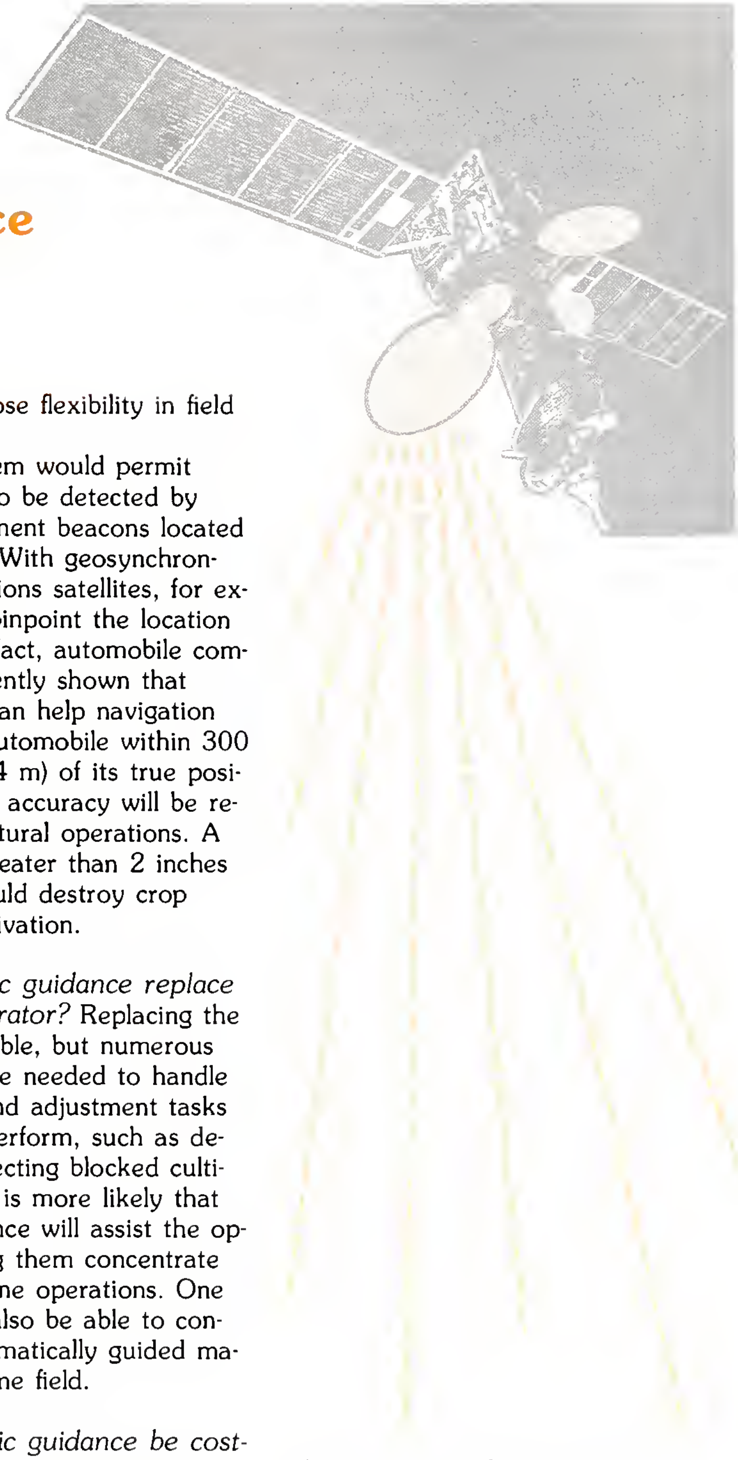
In summary, I would like to say that the university creates a stimulating atmosphere in spite of the endless tasks one must complete. Academia is an exciting place because individuals have the freedom to act, and they feel they are contributing actively to the good of the nation. Both industry and academia have a place in our society. Both have a vital role to play in agricultural mechanization. And both can learn from each other. Perhaps that's where I can help.

Roscoe L. Pershing, professor and head, Department of Agricultural Engineering ☐



Where the action is: Agricultural Engineering Sciences Building, University of Illinois at Urbana-Champaign. Research in agricultural engineering will profoundly affect the future of agriculture.

Bringing Automatic Guidance Down to Earth



Carroll E. Goering

It's spring planting time. A planter follows the tractor along the curved contour around the slope of the hill. In the soil, the root zones are virtually free from compaction because the tractor and the implement wheels have been following precisely the same tracks for all operations performed in the last 5 years. How can the operator steer so accurately? Actually, he is adjusting the seeding, fertilizer, and herbicide application rates of the planter and doesn't seem to be steering at all. Just beneath the hood of the tractor, a microcomputer is using transmissions from communications satellites to calculate the tractor's position; the computer compares the information with a map stored in its memory and sends a correction to the steering system.

The scene described above is fictional, but it could very well become fact. With the introduction of agricultural automation, both farmers and researchers have begun to give serious consideration to automatic steering or "automatic guidance" as it is called.

Is automatic guidance feasible? The key factor is whether steering errors can be detected automatically. Although special-purpose sensors can detect crop rows, windrows, or furrows, they lack universality. In other words, they cannot switch field operations. If a grid of electric wires were buried in each field, a single sensor would be able to detect the wires and permit any machine to be guided automatically. For such an installation to be cost-effective, however, the wires would have to be used for at least 10 years. But then farmers would lose flexibility in field layout.

An ideal system would permit steering errors to be detected by means of permanent beacons located above the field. With geosynchronous communications satellites, for example, we can pinpoint the location of a vehicle. In fact, automobile companies have recently shown that these satellites can help navigation by locating an automobile within 300 yards (about 274 m) of its true position. Far greater accuracy will be required in agricultural operations. A steering error greater than 2 inches (about 5 cm) could destroy crop rows during cultivation.

Will automatic guidance replace the human operator? Replacing the operator is possible, but numerous controls would be needed to handle all the control and adjustment tasks that operators perform, such as detecting and correcting blocked cultivator shovels. It is more likely that automatic guidance will assist the operators by letting them concentrate on critical machine operations. One operator might also be able to control several automatically guided machines in the same field.

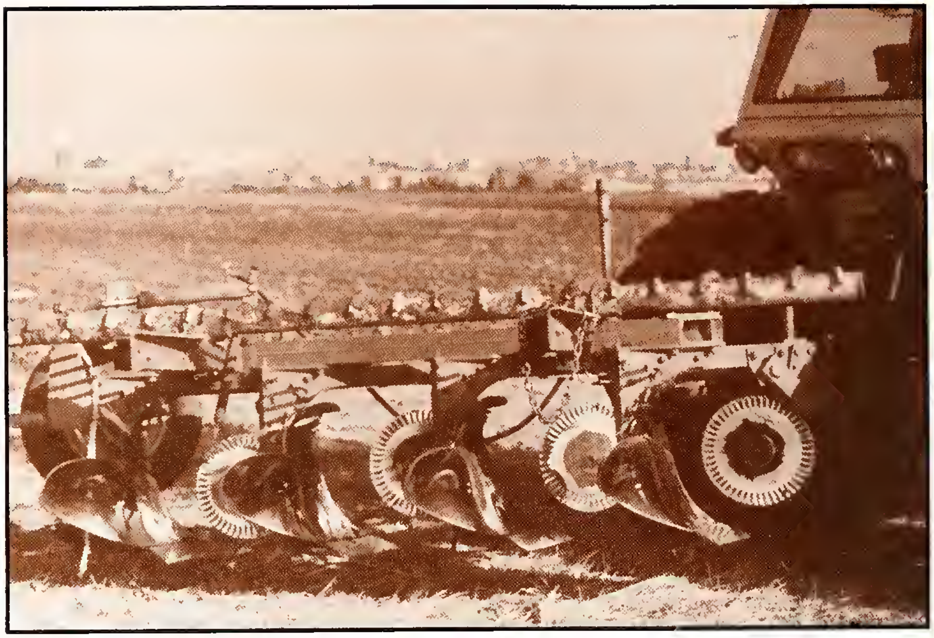
Can automatic guidance be cost-effective? Advances in electronics are reducing the costs of the necessary guidance components. To be economical, however, automatic guidance must increase a farmer's income or reduce costs of farming. If automatic guidance could confine all wheeled traffic to fixed paths, it would prevent compaction in the root zone. Under these conditions, yields would increase, paying for the more moderately priced components of automatic guidance equipment. Moreover, by allowing one operator to control several machines, automation would reduce costs.

If automatic guidance proves economically viable, it is highly possible that with advances in technology the scene described in the opening paragraph might become a reality.

Carroll E. Goering, professor of agricultural engineering □

Monitoring and Control of Field Machines

John W. Hummel



Draft control. A mounted moldboard plow with a hydraulic control system adjusts plowing depth according to the pulling force (draft) experienced.

American agriculture needs help! Our agricultural economy, particularly with reference to grain crops, has become dependent on exports. On the other hand, the demand in the world market for our grains and oilseeds has been diminishing since 1981. Although the decline in American agriculture has been affected by many factors beyond the producers' control (such as political policies and the strength of the U.S. dollar abroad), research suggests that improving production efficiency would allow U.S. producers to compete more effectively in the world market.

The individual efforts of farmers in Illinois are being supported by the activities of the Agricultural Experiment Station at the University of Illinois, where researchers are seeking different, cost-effective applications for new technology.

Control systems for improved efficiency. Mechanical controls, such as the engine governor, have been used very effectively to improve the efficiency of agricultural production. However, because of their complexity and the absence of appropriate sensors, mechanical controls are limited in their application. With the installation of hydraulic systems on tractors and machines, opportunities for control have expanded. Draft control is one such example. When a tractor's hydraulic system senses the increased draft (pulling force) of a plow, it automatically adjusts the depth of the plow.

The birth of the transistor nearly 40 years ago ushered in the electronic era; now, electrical, electronic, or related systems can monitor a machine's performance. With the help of such a capability, our food production system could leap forward as it did earlier in this century with mechanization, chemical applications, and plant breeding.

Localized management systems. Mechanization and electronics have stimulated our researchers to begin investigating a localized management system that will automatically adjust cultural practices to meet the needs of a specific area within a field. Such a system would be based on the principle of automatic navigation, which would determine the machine's exact position in the field. An on-board computer would determine the specific operation to be performed, and the machinery would permit "on-the-go" variations of the operation.

Although some navigation systems are already in use, they still need to be improved. Existing systems, however, such as Loran (Long-Range Aid to Navigation), may be able to serve the needs of the localized management system in situations that do not require precise position control.

The rapidly expanding storage and computational capabilities of minicomputers have allowed researchers to manipulate and store large sets of field data about soil types, soil moisture-holding capacity, weed infestations, previous crop yield, and other variables. As technology continues to develop, computational capability will continue to increase, but the cost per unit will decrease. Advanced technology will thus become more accessible to the small farmer.

"On-the-go" control of some machinery has also become a reality, permitting farmers to make precise adjustments in planting, fertilizer use, and chemical rates according to the immediate situation. Researchers hope to synchronize tillage practices with specific crop needs, local soil type and conditions, climate, and other factors. This "custom-prescribed tillage" should increase yields, reduce erosion, and save fuel.

Sensors. University of Illinois faculty and staff members, in cooperation with the United States Department of Agriculture, Agricultural Research Service, are conducting research to develop the sensors needed as key components in automatic control systems. These sensors will measure the effects of tillage operations on soil conditions.

To be able to control field-machine operations, particularly tillage operations, we must first establish a relationship between soil condition and a measurable electrical signal. We can

A wide-span carrier transports sensors and on-board equipment to collect data from the fields. The information can be used to make control maps for field operations.

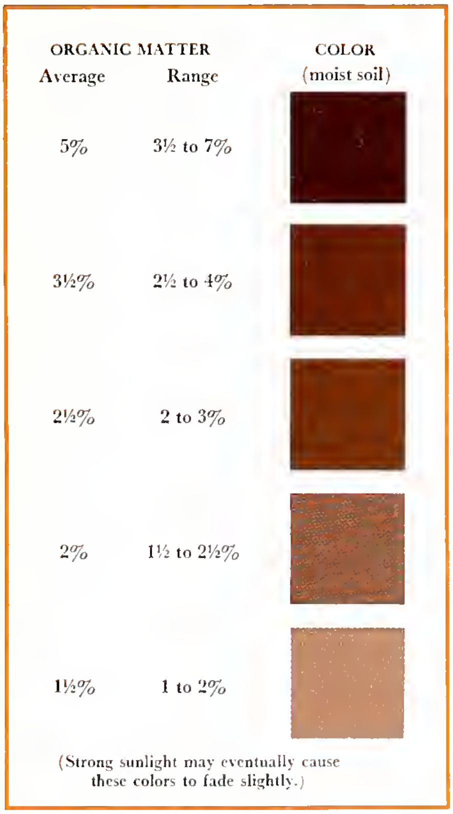


Fig. 1. A reproduction of J.D. Alexander's color chart for estimating organic matter in mineral soils in Illinois. The colors used here are only an approximation. *Actual pocket-size chart available from Department of Agronomy, University of Illinois at Urbana-Champaign, W-401 Turner Hall, 1102 South Goodwin Avenue, Urbana, Illinois 61801.*

then take the first step in a control system — monitoring. Some key soil conditions change slowly over time. Data on these conditions could be entered into an on-board computer and used to control machine functions. Soil pH is one such condition. For a liming operation, a control map of the field could be made well before the actual field operation and stored in the on-board computer's memory. The computer would, on the basis of this information, prescribe the application rate for the lime.

Other soil conditions change rapidly with time. Depending upon the variable being controlled, they may need to be monitored during the field operation. Soil moisture, for example, might be sensed and the information used immediately to adjust planting depth.

Sensing soil organic matter. For some soil-applied herbicides, the amount of herbicide needed for adequate control depends on the organic matter content of the soil. In fields where organic matter content varies greatly, a uniform broadcast application may damage the field crop in part of the field and fail to control the weeds in the portion with a higher soil organic matter content. An appropriate sensor could dynamically control the herbicide application rate while the equipment is being operated in the field.

A color chart for estimating the organic matter content of mineral soils in Illinois was devised more than fifteen years ago by J.D. Alexander in the Department of Agronomy. Alexander classified soils according to their color into one of five overlapping ranges of organic matter content (Fig. 1).

We have extended Alexander's idea and have analyzed the light reflected from soils over the entire range of visible wavelengths, correlating it with organic matter content. Our researchers have sampled and studied 30 typical Illinois soils with textures ranging from sand to clay and with organic matter content ranging from 1 to 6 percent.

We have used a computerized laboratory reflectance spectrophotometer (an instrument used to measure the relative intensities of light in different parts of the spectrum) to identify four light wavelengths. The reflected light energy of these wavelengths, when mathematically combined, correlated closely with soil organic matter content. Initial attempts to transfer this technique to a portable field unit were unsuccessful.

A color sensor that uses the color of the reflected light to determine the soil's organic matter content was also tested. The light reflected from the soil surface was filtered to obtain two of the primary colors, red and green. These two light bands, along with the unfiltered reflected light, were directed to three phototransistors. Ratios of the three signals were formed and correlated with soil organic matter content. By combining the information from all three signals, we were able to predict the organic matter content of Illinois mineral soils precisely enough to control herbicide application rates in many field conditions.

Researchers are still intrigued by the close correlation of reflected light with organic matter content that is obtained by use of a computerized reflectance laboratory spectrophotometer. A portable spectrophotometer is being developed for real-time anal-

yses of the soil's physical properties.

After a system such as the one described above is able to accurately sense soil organic matter content across all field conditions, a similar unit might be used on field sprayers to improve the application of soil-applied herbicides. Crop producers would benefit from reduced herbicide costs and less crop injury; the general public would benefit from the decrease in environmental hazards.

Soil moisture sensing. Soil moisture is essential for seed germination and plant growth. If the soil's moisture retention capability could be mapped, then farmers could control the application rate of fertilizers by applying high rates where moisture retention is greatest. In addition, farmers could use real-time analysis of the soil moisture to evaluate the effects of their tillage operations.

With the help of the computerized reflectance spectrophotometer, we have also identified two wavelengths in the near-infrared region (NIR) that are correlated to the moisture of 30 typical Illinois soils. (Reflected light in the near-infrared region has already been used to detect the moisture content of biological materials.) Our research could lead to the development of a system that would sense soil moisture at different depths and locations throughout a large field. Researchers are developing a portable NIR analyzer to measure real-time soil moisture.

The future of systems that automatically control and monitor field machines will depend on the availability of technology, the reliability of the system, and its cost-effectiveness. The two sensing concepts being evaluated by engineers at the University of Illinois could lead to feasible field-sensor systems. It remains to be seen whether industrial engineers will be able to design and develop these concepts, converting them into reliable and economical systems. Automatic controls and the monitoring of field machines will become increasingly important features of future crop production sytems and should play a role in eventually helping farmers improve production efficiency.

John W. Hummel, associate professor of agricultural engineering and agricultural engineer, U.S. Department of Agriculture, Agricultural Research Service ☐

Portable spectrophotometer in use. Author John Hummel watches as his graduate research assistant analyzes soil moisture content by holding a soil sample under the near-infrared reflector's probe. Light from the fiber-optic conductors strikes the surface of the soil sample. The light is then reflected back, and light intensities are electronically decoded to predict soil moisture. The results of the analysis appear immediately on the monitor (computer screen).

Corn Quality — Does Mechanization Help or Hurt?

Gene C. Shove and Marvin R. Paulsen

Over the past forty years in Illinois, the methods used to harvest, dry, handle, store, and market corn have become increasingly mechanized. Although production efficiency has improved, the mechanization of the grain-handling processes has created an environment that is more hostile to cereal grains than the environment created in the past by manual labor.

For a majority of farmers, corn that was once harvested on the ear with a corn picker and then dried and stored in a corn crib is now harvested and shelled with a high-capacity combine, artificially dried with a high-speed dryer, and stored in a steel or concrete bin. Grain that was mainly grown in the past for on-farm animal use is now produced as a cash crop to be marketed and transported throughout the world. The changes described have been possible because of improvements in agricultural mechanization, which have allowed producers to harvest, dry, store, and transport large volumes of grain efficiently.

Unfortunately, the mechanization that makes the present corn-marketing system possible also forces the grain into prolonged contact with iron, steel, and concrete, subjecting it to rather harsh treatment. Thus, although the mechanization of grain production and transportation has helped make the United States "the breadbasket of the world," this mechanization has generated a new concern — the need to maintain and improve grain quality.

Benefits of mechanization. The importance of mechanization for grain production cannot be denied. Larger acreages and higher volumes

than before can be handled. In addition, both labor and losses are reduced. And finally, more of the grain actually produced in the field is available to the end user. (We can define the end user as the one who transforms the grain into a consumer product — whether that product be animal feed or human breakfast cereal.)

Combines harvest the crop quickly, and artificial drying allows for the wetter grain to be harvested early with fewer field losses. Storing grain in steel bins protects it from rodents and insects. Mechanical aeration keeps the grain cool by controlling the temperature.

Fig. 1. Normal and stress-cracked corn. The kernel at the far left is undamaged. The other three kernels (left to right) show an increasing number of stress cracks. Often, the cause of damage is high-speed, high-temperature drying.

Fig. 2. Low-temperature drying of corn: an electric fan blows air into a grain bin.

Drawbacks. Despite the advantages listed, mechanization has had some undesirable effects on grain quality. Rapid harvest, such as the field shelling of corn with combines, can damage the grain kernels physically. High-speed, high-temperature drying can also cause physical damage; in addition, it creates stress cracks in the kernels, making the grain more susceptible to breakage during subsequent handling (Fig. 1). Grain quality is also adversely affected by most grain-handling equipment and the frequency with which the grain is handled on its way through the marketing system.

Grain quality at the time of harvest is usually excellent and generally remains quite good through the first phase of storage. However, the procedures used during this early period on the farm or at the country elevator will affect grain quality when the grain is handled at a later stage.

Specifically, two factors contribute to the down-grading of grain quality, particularly corn: improper management of grain moisture and inadequate procedures for handling the grain. The problem is not restricted to any one group of handlers or one procedure. For example, the farmer may dry grain at too high a temperature, which will make the grain very susceptible to breakage; the manager of the country elevator may not have adequate aeration equipment for controlling grain temperature; or the exporter may blend grain at too wide a moisture range for safe shipment.

Solving the problem. Mechanization, then, has created certain problems regarding grain quality. But, paradoxically, mechanization can also solve many of these problems — as our research indicates. For example, low-temperature drying systems and combination high-and-low temperature drying systems can greatly reduce stress cracks during the drying process (Fig. 2). Breakage caused by handling can be decreased by reducing the height at which grain is dropped. In addition, using the following mechanical devices will also reduce breakage: flow retarders; larger capacity screw conveyors operated at slower speeds; large, slow-speed buckets on bucket elevators; and inclined belts. Relatively little grain breakage occurs when grain is conveyed on belts where little or no relative movement occurs between the grain and the conveyor belt (Fig. 3). Handlers can use breakage susceptibility tests to identify highly susceptible grain. This grain can thus be segregated and used for those purposes for which broken kernels are acceptable.

As researchers, we have the technology and expertise to improve and maintain grain quality by improving engineering design in many ways. For example, researchers at the University of Illinois have developed a microprocessor control system to regulate fans on a low-temperature drying sytem. We are also able to measure grain quality characteristics that are important to the final user. However, so long as the market and price systems do not provide the incentives for their use, these improvements are not likely to be implemented.

Supply and demand. The need for better quality grain and for the equipment to produce that quality are interrelated. If there is no demand for measuring new quality characteristics, then the incentive to meet the demand is also limited.

Often, however, the development of technology precedes marketing recognition. For example, the breakage tester was developed in its elementary stages many years before dry millers recognized that they could increase their product yield and value by selecting corn that had passed the breakage susceptibility test (Fig. 4).

In general, mechanization comes in response to economic needs. When producers have to reduce the cost of labor, produce a larger volume per unit of resources, or improve the value of the product, they will turn to mechanization.

The old adage, "necessity is the mother of invention," could be paraphrased to read: "Economic incentives spawn the creative development of technology." The equipment for blending grain of varying moistures to achieve a precise moisture content is a case in point. The equipment was developed when sellers recognized that if corn were more accurately blended, their profits would increase.

Recently, when 2 million bushels of corn (50,803 t) were loaded on an ocean-going vessel, over 40 percent of the sublots of 60,000 bushels each (1,524 t) were blended to exactly 15.0 percent — the moisture percentage specified on the contract. Although the grain was drawn in varying amounts from different shipping bins where moisture ranged from 14.2 to 15.8 percent, the overall average for the entire shipload was 14.9 percent. Such accuracy is only possible through engineering, which receives its impetus from economic needs.

Much still remains to be done to maintain the quality of grain in its long journey from the producer to the final user. Mechanization has already played an important role in that journey. It will continue to do so as long as agricultural scientists emphasize grain quality and research ways of improving it, keeping in mind the demands of the market.

Gene C. Shove, professor, and Marvin R. Paulsen, associate professor, Department of Agricultural Engineering □

Fig. 3. Grain from an export elevator bin is carried on a conveyor belt to an ocean-going vessel.

Fig. 4. Co-author Marvin Paulsen (background) supervises a breakage susceptibility test. Corn dropped into the feed hopper is channelled into a centrifugal impeller that hurls the kernels against a vertical, cylindrical wall. Damaged kernels are then separated. Researchers have been using breakage susceptibility testers at the University of Illinois for the last seven years.

Farm Machines, Farm Labor, and Federal Taxes

Donald L. Uchtmann

This article is based in part on an article published by D. L. Uchtmann and J. T. Cross in The American Journal of Tax Policy *(volume 3, Spring 1984). The article appeared under the title, "The Effects of Tax Policy on the Structure of Agriculture: Tax-Induced Substitution of Capital for Labor."*

Over the last 50 years, American agriculture has been mechanizing at a very rapid rate. According to the 1984 economic report of the President, the amount of capital used by each farm worker increased fifteenfold between 1930 and 1980. The report also said that contemporary agricultural operations use $43,000 worth of equipment per worker — about twice the average for all workers in the United States. As a result, we have in the United States the most mechanized agricultural system in the world.

A number of policy issues are raised by the phenomenon of rapid agricultural mechanization. This article focuses primarily on one of these issues — the extent to which federal tax policy has encouraged mechanization. Before proceeding, however, it will be useful to survey briefly the two following, related issues.

Have the benefits of mechanization outweighed the costs? This issue has been of concern to human beings ever since the Industrial Revolution. The benefits of agricultural mechanization are many. This mechanization releases human beings from much hard, tedious labor — such as stoop labor in harvesting vegetable crops; increases the productivity of each farm operator and worker so that persons remaining in agriculture can enjoy a higher standard of living; frees human resources being used in food production so that these resources can be absorbed into the industrial, manufacturing, and service sectors of a dynamic economy; reduces production costs for farmers and food costs for consumers; and increases the total quantity of food so that an expanding national and world population has enough to eat.

A price, however, has to be paid for the benefits listed above. For example, some displaced workers have not been reabsorbed elsewhere into the economy; the decline in farm populations may have adversely affected many farming communities; and some farmers may have overmechanized with borrowed capital. As a result, farmers may find it difficult to survive high interest rates, low commodity prices, and declining land values.

Does mechanization create unemployment? This related issue has been highlighted by recent litigation in California in the case of the *California Agrarian Action Project versus the Regents of the University of California*. The suit was filed on behalf of 19 farm workers who were displaced by a mechanical tomato harvester developed by the University of California at Davis.

Plaintiffs allege that the university's basic goal of mechanization research displaces farm workers, eliminates small farmers, hurts consumers, impairs the quality of rural life, and impedes collective bargaining. Although the judicial question is whether the university is following legislative and constitutional mandates in allocating public funds for research projects, the final outcome of this lawsuit will surely affect the public's perception of agricultural mechanization and its benefits to society. The case is still pending.

Having discussed related issues, let us turn to the key issue — whether the federal tax laws have encouraged mechanization at a greater-than-optimal rate. This issue is especially timely because of the proposed changes in the federal tax structure currently under review by the House Ways and Means Committee.

Mechanization and the federal tax structure. Tax policy does seem to have influenced the trend to substitute capital for labor in agriculture. In this context, the following tax provisions need to be examined more closely: accelerated depreciation, investment tax credit, and social security and unemployment insurances.

Accelerated depreciation. Under the Accelerated Cost Recovery System (ACRS) created by the Economic Recovery Tax of 1981, the cost of machinery and equipment can be depreciated much faster than the useful life suggested by the asset. For example, the cost of a pick-up truck can be depreciated (fully deducted) in just three years, and the cost of a tractor in just five years. The useful life of these assets is clearly longer than their write-off periods. Thus, farmers and other businesses can take greater deductions for depreciation in early years; and early deductions are worth more than later deductions. This rapid write-off decreases the after-tax cost of purchasing machines and equipment.

In addition, the progressive tax rates increase the benefits of acceler-

Mechanization may displace farm workers, who must be absorbed elsewhere into the economy.

Photograph reprinted from *Migrant Farm Workers: A Caste of Despair* by Ronald L. Goldfarb (The Iowa State University Press, Ames: 1981). By permission of the author.

ated depreciation in proportion to the taxpayer's taxable income. For example, a $10,000-deduction saves $5,000 in taxes if the farmer is in a 50 percent tax bracket; the same deduction saves only $2,500 if the farmer is in a 25 percent tax bracket.

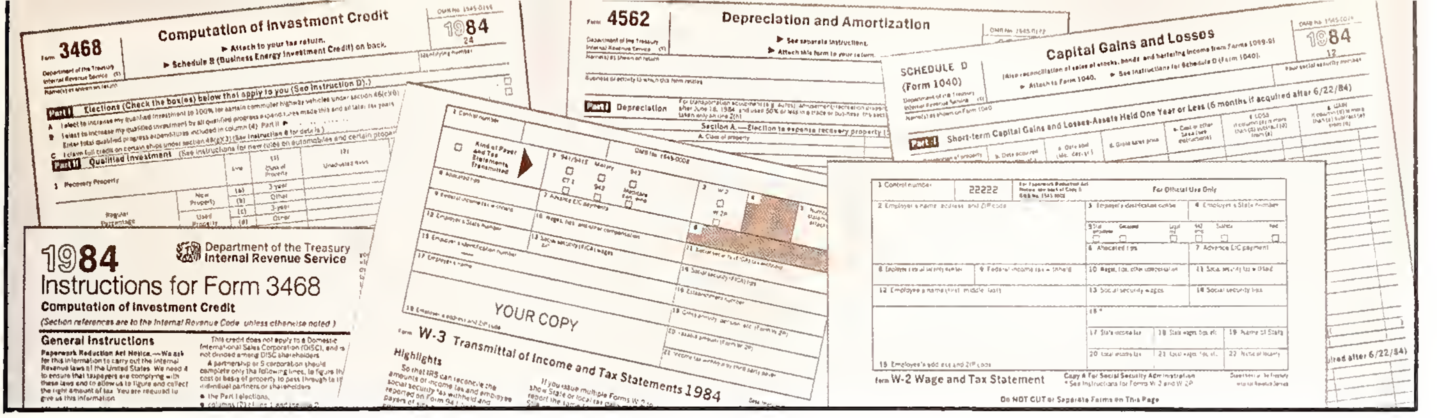
Investment credit. The Internal Revenue Code currently allows a tax credit of 10 percent of the cost of "Section 38 property," which includes investments in most agricultural machinery. Thus, if a farmer were to purchase a $10,000-machine, the farmer's after-tax cost would actually be $9,000 after the 10 percent investment credit is allowed. If a tax benefit (say the 10 percent deduction) is available to those who make a capital investment (the $10,000-machine), the farmer has an incentive to purchase the machine. This incentive may be stronger than the incentive created by accelerated depreciation because the benefit of the investment tax credit is almost immediate, whereas the benefits of accelerated depreciation are spread out over several tax years.

Social security. When Congress passed the original Social Security Act in the 1930s, farm workers and self-employed farmers were not eligible for benefits. Gradually, however, these benefits were extended to agricultural workers, and by the end of the 1970s approximately 2 million farm laborers were participating in the social security program.

Farmers employing workers must pay the employer's contribution to social security (currently 7 percent of the cash wage bill), a tax that sometimes raises the cost of labor above that of machines. In addition, the system requires record-keeping, which adds to the employer's costs. By increasing the cost of labor, the social security system encourages mechanization because farmers substitute machines for labor.

Unemployment insurance. The unemployment insurance system generates another tax on labor. As of January 1, 1985, agricultural employers paying out cash wages of $20,000 or more in any calendar quarter, or who consistently employ 10 or more persons, must pay a tax of 6.2 percent on the first $7,000 of each worker's annual salary. The tax money is used to help provide a cushion for the employee in the event of unemployment.

Unemployment insurance should affect the use of labor in the same manner as social security does be-



cause both artificially increase the cost of labor. The unemployment insurance provisions, however, make less impact. Only about one-third of the agricultural work force is employed by persons paying $20,000 or more per quarter in cash wages or consistently employing 10 or more persons. Hence unemployment taxes are not a factor for about two-thirds of the individuals employed in agriculture.

In summary, then, accelerated depreciation, investment credit, social security, and unemployment insurance become incentives for farmers to buy machines rather than to hire labor. The tax provisions artificially reduce the cost of capital and increase the cost of labor. Yet for several reasons farmers may not substitute capital for labor or may do so only to a smaller degree than predicted.

First, capital is generally only available in large increments because machines are not easily subdivided. In contrast, the use of labor is much more flexible: the farmer can hire any number of full- or part-time employees or give overtime to existing workers.

Second, energy prices have generally increased in the last decade. Mechanization requires power, and power requires fuel or electricity. High energy prices and a fear of price increases deter the farmer from mechanizing further.

In spite of the existence of these and other disincentives, many persons believe that the tax policy has encouraged farmers to substitute capital for labor in agriculture at a faster rate than they would have without the tax provisions. However, very little empirical data either support or refute this proposition. Assuming for the sake of argument that the tax policy has encouraged mechanization, the following question still remains: Is the tax policy consistent with our agricultural policy?

A comparison of federal tax policy and agricultural policy. The following goals have traditionally shaped agricultural policy in the United States:

- To supply adequate food for the populace
- To provide a decent income for farmers
- To encourage the conservation of resources
- To improve conditions of agricultural labor
- To preserve family-sized farms and rural communities

In general, the tax policy, by favoring capital over labor, serves the goals of our national agricultural policy. The provisions artificially reduce costs and thus encourage the use of machines, providing larger quantities of food at lower prices while maintaining a decent profit level for farmers. Both farmers and consumers have benefited from these effects. Furthermore, the substitution of capital for labor has allowed the remaining farm labor force to make tremendous gains in productivity. Wages have increased as a consequence.

In some respects, however, tax policy seems to conflict with agricultural policy. By encouraging the use of fuel (through more machinery) and possibly contributing to increased erosion (because some large machines are not well suited to contour farming) the tax provisions have pressed agriculture into using up limited resources and violating the policy of resource conservation. In addition, by displacing some farm workers, the tax provisions may have exacerbated problems of both rural and urban unemployment. Finally, the tax-induced mechanization of agriculture, to the extent that it increases farm size and reduces rural population, may be diminishing the quality of rural life. When the number of farmers on the land decreases, it means fewer shoppers in rural stores, fewer students in the schools, and fewer worshippers in the churches. The viability of rural life is threatened when stores, schools, and churches close.

Should government change the tax policy to remove the incentives for capital and disincentives for labor? The government must weigh the benefits afforded by the tax provisions to consumers, farmers, and employed agricultural workers against the costs imposed on unemployed agricultural workers, rural communities, and scarce resources.

In addition, policy makers should realize that the purely economic incentives for farm mechanization are likely to continue. Other factors, such as technological development, increasing real wage rates, and price support programs, have also contributed to the mechanization of agriculture. Even if the incentives for capital investment and the disincentives for using labor are removed, the trend toward mechanization will be not be reversed; it will merely slow down.

Donald L. Uchtmann, professor of agricultural law ☐

Agricultural Technology in Developing Countries

Alfred G. Harms

Alfred Harms has completed long-term assignments for the University of Illinois in India, Sierra Leone, Peru, and Zambia.

Almost 75 percent of the world's population is sustained by food that is produced on farms where mechanization is minimal. In developing countries, very often, mechanization means using the hoe, machete, or axe. These and other hand tools are the means of agricultural production, both for traditional, subsistence farmers and emerging, commercial, small-scale farmers. Mechanization can be seen at different stages of its evolution in various developing countries.

Stage 1. The first step in the evolution of mechanization is the adoption draft animals to pull both plows and carts. Later, when the land is better cleared and planting patterns are more stable, animal-drawn cultivation comes into use. In tropical Africa, however, the use of animals for power is hindered by the prevalence of the tsetse fly. Horses, mules, oxen, and even humans, when bitten by the tsetse fly, may be afflicted with sleeping sickness.

In many countries, the mechanization process has been accelerated by governments that have provided tractors and related implements. Equipment is made available to farmers under special tractor-hire schemes directed toward land-preparation.

Generally, in the first stage of mechanization — in which animal power and simple implements are employed — productivity increases. But usually this productivity does not displace the worker.

Stage 2. The next stage embraces the remainder of farm operations. Farmers begin using rudimentary machines to ease the arduous task of threshing and shelling. Human beings work the smaller, simpler machines, and small internal combustion engines power the large threshers. In drier areas, pumps are used for irrigation at this stage of development.

The productivity of farm labor (output per worker) increases in the secondary phase of mechanization. But unless farm acreage increases, mechanization mainly replaces labor. If one farm worker with a small thresher does the work of five using hand methods, then four must find other work.

Stage 3. The third stage involves the use of more power and of complex, sophisticated machines. It usually occurs in more developed countries that are experiencing parallel industrial development. At this stage, agricultural laborers migrate to factories in urban areas and farmers find it necessary to replace labor with machinery. As a consequence, the productivity of farm labor increases substantially. Farmers must, however, increase the size of their farms or hire out to neighboring farmers in order to justify the greater investment in improved machinery.

Mechanization in developing countries is subject to several critical restraints. The farmers lack capital to purchase machines, and many countries lack the foreign exchange to import new equipment and spare parts. Thus machines and power sources are often in short supply. The more developed countries, however, such as India and Brazil, are manufacturing their own equipment.

Farmers generally lack the knowledge and experience to operate and manage complex machinery. In addition, the facilities to train farmers are limited. In some African countries such as Zambia and Sierra Leone, potential users of animal power are at a disadvantage because cattle are owned by specific tribes or regions.

As a rule, government policies have favored urban populations with cheap food, which means that farmers have received low market prices for their surplus production. This condition discourages farmers from mechanizing and substantially increasing their production.

Alfred G. Harms, associate professor of agricultural economics □

A farmer in India uses a bullock-drawn plow to till his fields. Agricultural mechanization in India ranges from the developing stage to the developed. It is very possible that fairly sophisticated machinery might be in use on a neighboring farm.

For Whom the Tractor Toils

Sam H. Johnson III

During January and February 1985, professors Sam Johnson and Joseph Campbell (from Cornell University) were in Indonesia as members of a team reviewing the Agricultural Mechanization Extension Project of the International Rice Research Institute (IRRI). Located in the Philippines, IRRI has a global mandate to increase rice production in developing countries.

An Indonesian farm worker operates a two-wheeled tractor in a rice field. Among the onlookers is the farm worker's wife — the woman who owns the farm and makes related decisions, such as the decision to mechanize.

In mid-January, the 83-degree (28° C) weather in Sumatra, Indonesia, was a welcome relief from the cold, snowy winter of the Illinois plains. It was especially pleasant to be in a lush, green West Sumatra valley, standing on the edge (bund) of the soon-to-be-planted rice field, watching the young British volunteer teach the Indonesian farmer and his son. The two were learning how to use their new two-wheeled tractor, designed at the International Rice Research Institute (IRRI) in the Philippines. However, the presence there of a slender Minangkabau woman was something I did not expect. Not only was she remarkably good-looking in her colorful sarong, but she was also involved in what — elsewhere in Asia and often in the United States — is considered men's work. Intrigued by her presence, I asked the local extension agent about her. He told me that she had always been interested in agricultural mechanization and had come to see how well the two-wheeled tractor puddled the rice field. Finding his answer even more surprising, I asked him if he would translate so that I could ask the woman some questions. I thus proceeded to try to learn more about her interests and also about the attitude of women in the village toward agricultural mechanization.

As soon as the woman spoke, I realized that she was educated (later I found out she was a school teacher) because she spoke to the extension agent in Bahasa Indonesia — the national language — rather than Minangkabau, which is quite different. (This was better for me, because although not fluent in Bahasa Indonesia, I at least have the rudiments of the language from a tour in Malaysia during the late 1960s when I was a Peace Corps volunteer.) In response, she indicated that when irrigation was introduced, the village had effectively more farmland than water buffaloes to cultivate the land. As a result, the villagers had become interested in the small IRRI tractor, which can plow more land than a buffalo and can do it faster. She stated that the introduction of tractors does not create any social problems because the responsiblility for land cultivation lies directly with the landowners and tenants and involves no other groups in the village or the area.

Since I knew that transplanting rice is solely the job of village women, I asked how they would feel about rice transplanters. I also knew that the mere suggestion of rice planters had caused social upheaval in Java. I was therefore startled when she answered that the women would be happy, that rice transplanting was an albatross borne solely by the women, and that they had better things to do with their time! When asked to elaborate, she said that the village women could make handicrafts, market produce, weave silk, or grow vegetables for cash, all of which paid better and were less tedious than transplanting rice.

As I left, I saw the woman standing on the edge of the rice field, discussing the merits of the tractor with the farmer. On the drive back to Padang that night, I asked the agricultural economist in our group about the woman's comments. Her answers seemed quite at odds with conventional wisdom relating to the role of women in development. The economist, who was also a Minangkabau, explained it quite simply: Minangkabau society is matriarchal. All the land, including the fields where we had been standing, belongs to the women of the village. The farmer I had seen was plowing

not his own land as I had assumed, but the land of his wife. Any land left fallow was money out of the wife's pocket, and she was determined not to let this happen.

The degree of agricultural mechanization in Indonesia varies widely from island to island, and even within an island it is not homogeneous. Obviously this mechanization is at a different level than mechanization in the United States. It also differs from the type of mechanization found on the Asian subcontinent. Yet, among the rural population in West Sumatra, particularly the Minangkabau, mechanization has been eagerly accepted. This acceptance has been, interestingly enough, more a function of the women's willingness to invest than the men's desire to innovate.

Sam H. Johnson III, associate professor of agricultural economics □

Rice fields in Sumatra. Agricultural mechanization has been eagerly accepted in this part of Indonesia.

And miles to go before they sleep. Horse-logging operations were still common in the early decades of this century.

Photograph reprinted by permission of Forest History Society, Inc., Durham, North Carolina.

Advances in Forest Harvesting

Poo Chow and Gary L. Rolfe

Tree-harvesting operations have undergone vast changes over the centuries. Compared with the past, the most obvious difference today is that the process has become increasingly mechanized. Hand- and horse-logging are now largely obsolete; the axe, the crosscut and bow saws, and the skidding horse with its accessories have practically disappeared from commercial timber-harvesting operations.

Most cutting is now done with power chain saws. A four-wheel-drive skidder with rubber tires transports the bulk of the cut material out of the woods. All trucks are powered by diesel rather than gasoline engines. Truck loading has been almost completely mechanized, and practically all of it is now done with hydraulic grapple loaders mounted either on the logging truck itself or on a separate vehicle. This change has already increased the productivity of forest operations. However, new machines and methods are continually being developed. In recent years, for example, mechanized tree harvesters and mobile whole-tree chippers have been introduced. Because of all these advances, present-day foresters must be mechanically more sophisticated than their counterparts of the past. Today, foresters must be able to understand, operate, and maintain engines and hydraulic systems and their components, including electronic systems.

Tree harvesting includes all operations from cutting the stump to delivering the tree to the mill or wood-processing industry. With the evolution of these operations has come a whole new technical vocabulary. Foresters speak of felling, delimbing, bucking, and transporting trees to the roadside for loading and hauling. Transporting trees to the roadside is commonly termed *skidding* if trees are dragged on the ground by tractor; *forwarding* if they are transported in the bunk of an off-road vehicle; or *yarding* if they are moved by cable, balloon, or helicopter. Some major operations involved in tree harvesting are discussed below.

Felling. At present, different methods are used to cut (fell) standing trees. Different machines are used, ranging from chain saws to complex track-type vehicles known as feller-bunchers.

Tree-harvesting operations in modern times have been simplified by machines such as the whole-tree chipper. The operator uses hydraulic equipment to load the trees onto the conveyor and to feed them into the chipping machine. A whole tree can be reduced to chips in a matter of seconds.

Photograph of "Total Chiparvestor" reprinted by permission of Morbark Industries, Inc., Winn, Michigan.

Chain saws came into general use in the mid-1950s. Even today, certain conditions favor the use of chain saws for felling timber. Large hardwood trees and timber from wet areas, bottomland, or steep slopes usually require chain-saw felling. The operation demands only a small capital investment. The advantage of using chain saws is that the site is not disturbed as it is when large machines are used. Howevever, chain saws are hazardous to the operator. They are labor intensive, low in productivity, and tend to leave high stumps.

Feller-bunchers are towing, mobile machines. Each machine is big enough to grasp a tree up to a foot in diameter (about 30.5 cm) in its mechanical hands and then cut it near the base with a single stroke of its hydraulic shears, leaving behind a few inches of stump. The machine then delimbs the tree. Some models will cut the stem into log lengths and may even store the logs briefly in a holding rack until a pile can be deposited at a location convenient to truck loaders. Such equipment works best on gentle terrain and in plantationlike forests. Feller-bunchers may run on wheels or on a steel-belted tractor. They are well suited to high production and to movement known as grapple-skidding.

Skidding. This operation involves dragging felled timber from the stump to a landing or deck where final preparation and loading take place. Logs are then transported to the market place. Methods of skidding have progressed greatly. Originally animals were used for moving timber; after that came the four-wheeled farm tractors, and then chain-belted (crawler) tractors. Now, highly specialized rubber-tired or tracked skidding equipment is used. The rubber-tired log skidder is lighter and faster than the crawler tractor and causes less soil compaction. However, crawlers allow for greater traction. Both wheeled and crawler tractors can be equipped to lift one end of the the log during skidding to reduce soil disturbance.

In mountainous or swamp areas where conditions prevent conventional harvesting, the cable-skidding or grapple-yarding systems can be employed. Cable skidding is similar to the conventional system described above except that a cable mechanism transports the logs. The system is like that used for a ski lift. The grapple-yarding system, as its name suggests, employs a grapple (claw-mechanism) on the cable to pick up more than one log.

Yet another moving unit consists of a mobile crane that lifts logs clear off the ground and hauls them as far as 1,000 yards (914.4 m). Logs are left at roadsides for pickup later by truck, so no special landing area is required. This system causes so little site disturbance that it is sometimes necessary to bring in additional equipment to work the ground and expose mineral soil for planting and regeneration.

Forwarding. When material is transported on a device that carries it clear above the ground, the operation is called forwarding. Forwarding machines are equipped with hydraulic loading systems. They are attached to the front end of a four-wheel-drive skidder that has another attachment at the back to carry a load of logs clear above the ground.

Both rubber-tired wheel and track forwarders are available. Wheeled forwarders cannot be used effectively on boggy ground. The track forwarder is therefore more suitable in areas where snow, ice, and boggy terrain exist.

Product preparation. Several functions are required to prepare a product to meet the buyers' specifications. Product preparation involves three steps: limbing, topping, and bucking. Removing limbs and tops from the felled trees are the first two steps. Bucking, which follows, consists of cutting a merchantable stem into measured lengths.

Balloon and helicopter logging systems. Both these systems are used in mountainous and swamp areas. The two systems provide alternate ways to transport logs to the storage area for hauling. The balloons used in logging operations derive their power from a volume of helium that is enclosed in an envelope made of dacron and lined with

Fig. 1. Schematic representation of a typical, modern whole-tree chipping operation. **A.** A feller-buncher seizes a tree and cuts it near the base with a single stroke. **B.** A grapple-skidder grasps the trunk in its claws and transports it to the chipping unit. **C.** Portable chipper. A loading boom feeds the tree — trunk, twigs, branches, and all — into the throat of the chipper. **D.** A chip van transports the chips to a mill, leaving the site clean and tidy.

Schema reprinted from "Harvesting developments for short rotation intensively cultured forests," *Forest Products Journal* (vol. 33, no. 3, 1983). By permission of the author, James A. Mattson, USDA Forest Service, North Central Forest Experiment Station, Houghton, Michigan.

neoprene. A balloon with a capacity of 530,000 cubic feet (15,008 m^3), filled with helium, will lift approximately 25,000 pounds (11.34 t). The weight will vary with temperature and altitude.

Logging helicopters are divided into three classes according to the weight they can carry:

Class 1 — more than 12,000 pounds (5.44 t)

Class 2 — 6,000 to 11,999 pounds 2.72 to 5.44 t)

Class 3 — up to 6,000 pounds (2.72 t)

To maximize their log-carrying capacity, the helicopters do not carry a full fuel load. Usually they carry only enough fuel for a 40-minute flight, with enough reserves for 10 minutes.

Both the balloon and helicopter systems are attractive because they cause little site disturbance during the logging process. However, they are subject to many problems: both are vulnerable to bad weather, particularly fog and winds; for helicopters to be economically feasible, large logging areas are necessary; both methods are very expensive compared with conventional harvesting systems.

Hauling. This term refers to the function of transporting wood products from the forest to various markets. Pulpwood and logs can be shipped on trucks, trains, and tractor-trailer rigs, which are diesel powered.

Whole-tree chipping. A whole-tree chipper consists of a machine that is capable of ingesting an entire tree — limbs, leaves, bark, and all — and reducing it to small chips of wood. The wood chips are used to manufacture pulp for papermaking and to generate heat for energy or fuel production. Logs can be chipped on-site or hauled to a mill for chipping. If chipped on-site, the chips are hauled to the mills in conventional highway rigs or chip vans.

A typical harvesting operation consists of mechanical felling and bunching, grapple skidding, and chipping (Fig. 1). Production varies from 100 to 400 tons (90.72 to 362.88 t) per day. The increased use of whole-tree chips for fiber and fuel in the early 1970s has made whole-tree chipping acceptable in the forest industry. It is estimated that by the early 1980s, over 800 mobile chipping units were in operation in North America.

Poo Chow and Gary L. Rolfe, professors, Department of Forestry ☐

In Progress

Before and After Farm Aid

The Farm Aid concert has come and gone, fulfilling its purpose of drawing national attention to the financial plight of the farming community. The event in Urbana-Champaign (which is already "Farm Aid I") received full cooperation from the College of Agriculture, says Dean John R. Campbell. He has commended the concert as a conscientious and humanitarian effort.

Campbell met with representatives of Willie Nelson's group after the concert to discuss expenditure of the money raised. The dean believes that some mechanism to authenticate individual needs is essential. He suggested that the College's Rural Route program (and others like it) be used to identify and evaluate those needs. He also proposed that an advisory board (consisting of leaders from national agricultural organizations) be formed to make financial recommendations. The dean expressed his opinions on the farm crisis and Farm Aid nationally through an article in *The New York Times* (September 25).

In the aftermath of the concert, two points relative to the College of Agriculture deserve special attention: (1) the involvement of the Office of Agricultural Communications and Extension Education (OACEE) in the event itself; and (2) the multipronged efforts within the College that were initiated long before Farm Aid and are continuing after it to deal with the crisis in practical terms. The concert, by its transitory nature, should remind us of the importance of these long-term endeavors.

OACEE involvement. Because the Farm Aid concert was a major media event, the media section of the Office of Agricultural Communications and Extension Education was actively involved.

Ray Woodis, media coordinator, worked closely with staff members at the University of Illinois News Bureau to develop a packet of "news backgrounders" for distribution throughout the country. Woodis also coordinated preconcert briefings. The background packets, which drew on College sources, covered a wide range of relevant topics.

Gary Beaumont, Grear Kimmel, Bill Cresswell, and Scott Parker, OACEE staff members, prepared news stories that were distributed nationwide via the office's "Today on the Farm" television program. Woodis says that as a direct result of the assistance provided by OACEE to the CBS news team covering the event, "Today on the Farm" is now being regularly distributed by CBS to more than 50 affiliates throughout the Midwest.

Specialists at work. In 1982, the Cooperative Extension Service started offering seminars and workshops to help farm families manage their finances. Since then, programs have expanded and proliferated.

Confidential service. One of the most outstanding of these programs is Rural Route, initiated in March 1985 with the help of a federal grant. Rural Route provides a toll-free telephone service and confidential farm financial counseling. According to Extension's assistant director Peter Bloome, the College has expanded its traditional role through Rural Route. Farm families, he says, need support in three ways: financially, legally, and emotionally. Rural Route and other programs strive to give that support.

Analysis. The crisis is being tackled on other fronts. A Task Force on Financial Conditions in Agriculture has recently been organized, chaired by David Lins, professor of agricultural economics. Lins says that the primary purpose of the task force is to provide information about farm financial conditions for legislators, policy makers, and the farm press. In addition, it evaluates policy proposals that affect Illinois agriculture. To examine financial issues in depth, Lins and his colleagues project outcomes for farms, using different economic scenarios.

Education. Richard Kesler, professor of farm management, says that Extension offers several financial management programs in Illinois each year. The thrust of these programs is educational. Farmers are made aware of the nature of their financial problem, of alternatives to consider, and possible courses of action. In addition, farmers are encouraged to take financial management courses via TeleNet, the statewide audio teleconferencing network operated by Extension.

Thomas Frey, professor of agricultural finance, emphasizes teaching farmers how to prepare and analyze their financial statements, particularly their balance sheets. Reference materials are provided by the Department of Agricultural Economics. While some farmers will discover from these programs that leaving agriculture is their best alternative, says Frey, others will find financial strength in farming.

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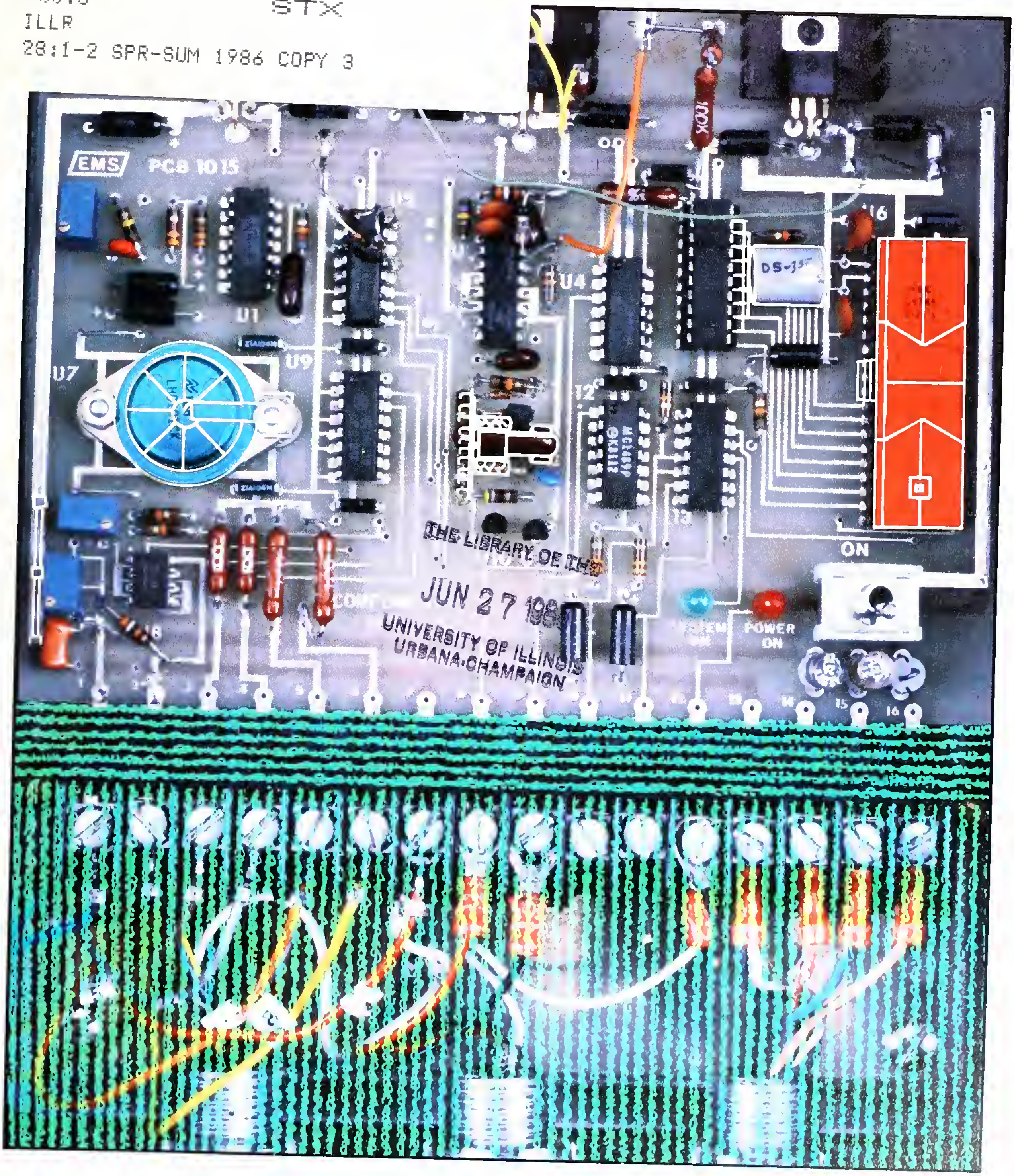
Winter/Spring 1986

Computers in Agriculture

Illinois Research

Agricultural Experiment Station
Spring/Summer 1986



College of Agriculture, University of Illinois at Urbana-Champaign, Volume 28, Numbers 1/2

1986 - Directions - 1996

New Directions with Computers

Since the beginning of time, human beings have continually invented devices by which to count and calculate — devices ranging from the abacus to the present-day computer. Each device has been an improvement on its predecessor, making a mark on the society of its time and increasing the speed and accuracy with which human beings calculate. In the 1970s, the microchip revolutionized methods of computation: a small piece of silicon launched us into the computer age.

The age of computers is characterized by some major trends that will profoundly affect our lives in the next ten years. Although these trends began earlier and are likely to continue well into the future, their impact will be most evident in this decade.

The trend of *computer-aided design* and *computer-aided manufacturing* (CAD-CAM) will shift toward *computer-integrated manufacturing* (CIM) as major businesses employ the computer more and more to improve design and manufacturing efficiency. The best minds from both industry and the university will be involved in computer-integrated manufacturing. Increasingly, the small computer will be emphasized. As in the case of the engineering workstation, the microcomputer will be used for personal input and connected to a network of larger computers.

Another trend is the use of *integrated data*. In the 1970s, the Harvard School of Business went on record with the accurate prediction that the challenge of the 80s would be data management. This function is extremely important because the computer explosion has caused data files to grow like Topsy, with no real planning. Today, most enterprises are accepting the challenge of moving, at some level, toward well-planned, integrated data resources.

Performing *concurrent tasks* is yet another trend that has been generated by computer technology. Let us, for example, take engineering tasks. In the past, these tasks were too often viewed as sequential. Design, drafting, and testing were completed long before any thought was given to manufacturing, that is, to the processes actually involved, tool design, and inspection. Now, most enterprises recognize the efficiency of concurrent tasks and teamwork and take these factors into consideration when planning a new product. The principle of concurrency applies to agricultural and other situations as well.

The new trends created by computers have also changed the direction of teaching, research, and extension. Modeling has become a major tool; researchers write accurate and complete equations for the modeling process and the computer finds the solutions.

Modeling has spawned simulation activities, ranging from simple mechanisms or quantitative analyses suitable for a microcomputer to those intended for giant supercomputers, such as weather simulation or large finite-element problems. More and more, results are being expressed graphically, sometimes in color, with animation.

Researchers at the University of Illinois have begun to successfully use artificial intelligence and expert systems for modeling "uncertain relationships." Here the computer simulates decision-making by an "expert," who must decide on a course of action on the basis of the best knowledge available, even if that knowledge is incomplete. This ability to handle uncertainty makes the computer's role in future technology even more certain.

Roscoe L. Pershing, professor and head, Department of Agricultural Engineering ☐

To the reader:

Starting with this volume of *Illinois Research,* the spring issue will be the first of the year (Number 1), and the winter issue will be the last (Number 4). In the past, the winter issue was Number 1. The present issue consists of Numbers 1 and 2; it is a combined spring/summer issue.

The Cover

The computer revolution is affecting all aspects of life. It will profoundly change agriculture. Our cover shows an interface circuit control board on which the artist has superimposed an aerial view of a farm. The merger of the farm scene with the board suggests the relationship between computers and agriculture.

"At a time unlike any in the past, we must envision the future."

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Contents

Computers in Agriculture

The Language of Computers: A Glossary

The computer lexicon is an ever-growing one. It encompasses the terminology of the researcher and of the personal computer user. It even pervades the vocabulary of those who dislike, ignore, or fear computers. The terms below, however, are limited: they are restricted to those that are relevant to this issue of *Illinois Research*.

access — to obtain data from computer memory or to store data in memory.

artificial intelligence (AI) — a subject of research in which computers are programmed to mimic human intelligence, using logic and reasoning.

analog computer — a computer that operates with numbers represented by directly measurable physical quantities, such as voltages or rotations, rather than digits.

algorithm — a precise formulation of a method for doing something. In computers, an algorithm is usually a set of procedural steps or instructions organized so that computer-processing generates the solution of a specific problem.

bit — a contraction of **bi**nary digi**t**, which is one of two numbers — 0 or 1 — used to encode computer data. The term is used widely as a synonym for binary elements, a constituent of data that takes either of two values or states (on-off, yes-no, zero-one). The smallest unit of computer information.

byte — a string of bits operated on or treated as a unit, usually representing one alphabetic or numerical character.

chip — a small piece of semiconductive material (silicon) that functions as an integrated circuit.

circuit board — a board on which the circuits of a microprocessor are attached.

coprocessor — an auxiliary processor that assumes certain functions in order to free the central processing unit; the speed of the operation is thus increased.

CPU — Central Processing Unit. The section of the computer housing the circuits necessary for integrating and carrying out operations.

data base — a collection of data files containing complete information on a particular subject, organized for rapid search and retrieval (often by computer).

data management — the functions of a control program related to acquiring, analyzing, storing, and retrieving data.

data processing — the processing of information through a series of systematic operations that control the input, storage, manipulation, and retrieval of data.

dedicated system — a computer system designed primarily for one purpose, such as word processing or graphics.

digital computer — a computer that operates with numbers expressed directly as digits.

digitizer — a unit that converts analog representations (such as a drawing or music) into digital form.

disk drive — a device that holds and spins magnetic disks. It has a read/write head by which it reads data from or writes data into storage.

download — to adapt programs and data files so they can be transferred from a central computer to a remote terminal to be stored there for use.

expert system — within the scope of artificial intelligence, this is a computer program that enables the computer to mimic the kinds of human behavior requiring intelligence, judgment, and experience with regard to a specified subject.

floppy disk — thin, flexible, magnetic disk used to record and retrieve data. The disk is contained within a protective cover.

front end — a software package for simplifying access to an electronic information service or to a mainframe or supercomputer.

gateway service — a single service providing unified access to multiple on-line information services.

hard disk — a magnetic disk made of inflexible material.

hardware — physical equipment and permanent components of the computer.

hipad — a device, like a mouse, that allows the user to input a point on the digitizer.

integrated circuit — a tiny complex of electronic components that is produced on a single substrate, usually silicon.

interface — an electronic component that allows one program, device, or system to communicate with another.

language — the commands, vocabulary, and conventions used to communicate information that will be handled by the computer and its related equipment.

laser printer — a printing device in which tiny beams of electromagnetic energy in the light spectrum (laser beams) are used to form images of the information to be printed.

mainframe — large computer, ordinarily servicing many users.

memory — the storage area in the computer where data can be copied, held, and retrieved.

menu — a list of alternative computer functions, usually presented on the display screen; the user can refer to the menu and select an option in order to carry out a desired procedure.

modeling — representation of a process, a device, or a concept through a mathematical or pictorial model.

modem — **mod**dulator-**dem**odulator. A device that converts digital signals from a computer into auditory tone variations and transmits them over standard telephone lines.

monitor — a display unit that resembles a television screen and is controlled by the computer.

online — operating directly and immediately through a terminal or keyboard connected to the computer.

parallel processing — a computer operation during which two or more central processors in the same computer operate concurrently to accomplish several individual tasks simultaneously.

peripheral — equipment that works in conjunction with the computer but is distinct from the central processing unit. Some examples are printers, disk drives, and terminals.

program — a set of instructions given to the computer that allows it to perform specific functions or tasks. The instructions must be expressed in a language appropriate for the computer.

real time — relates to data processing that occurs simultaneously with a process occurring outside the computer. The purpose is to measure, control, or influence that external process without delaying it.

robotics — the study of electronically and mechanically controlled movement that involves robots. Usually involves image processing by the computer, which enables the device to "see," "hear," and "feel."

simulation — a representation of the characteristics of a physical or abstract system (such as weather or the design of an aircraft) through another system (such as a computer).

software — computer programs.

spreadsheet — software that generates a worksheet, often two-dimensional, similar to that used in a business or scientific undertaking. The user can indicate the relationships between data entries. When the data are changed, the program can readjust the relationships immediately.

supercomputer — the fastest and most powerful computer available at any given time.

user friendly — qualities of the computer that make it easy to use.

word — a string of bits consisting of two or more bytes.

Computers in Agriculture

Carriages without horses shall go,
And accidents fill the world with woe.
Around the world thoughts shall fly
In the twinkling of an eye,
Under water men shall walk,
Shall ride, shall sleep, shall talk;
In the air men shall be seen
In white, in black, and in green.

Mother Shipton, *Prophesies.*
(Compiled in 17th century England.)

Computers: Extensions of the Mind

Donald A. Holt

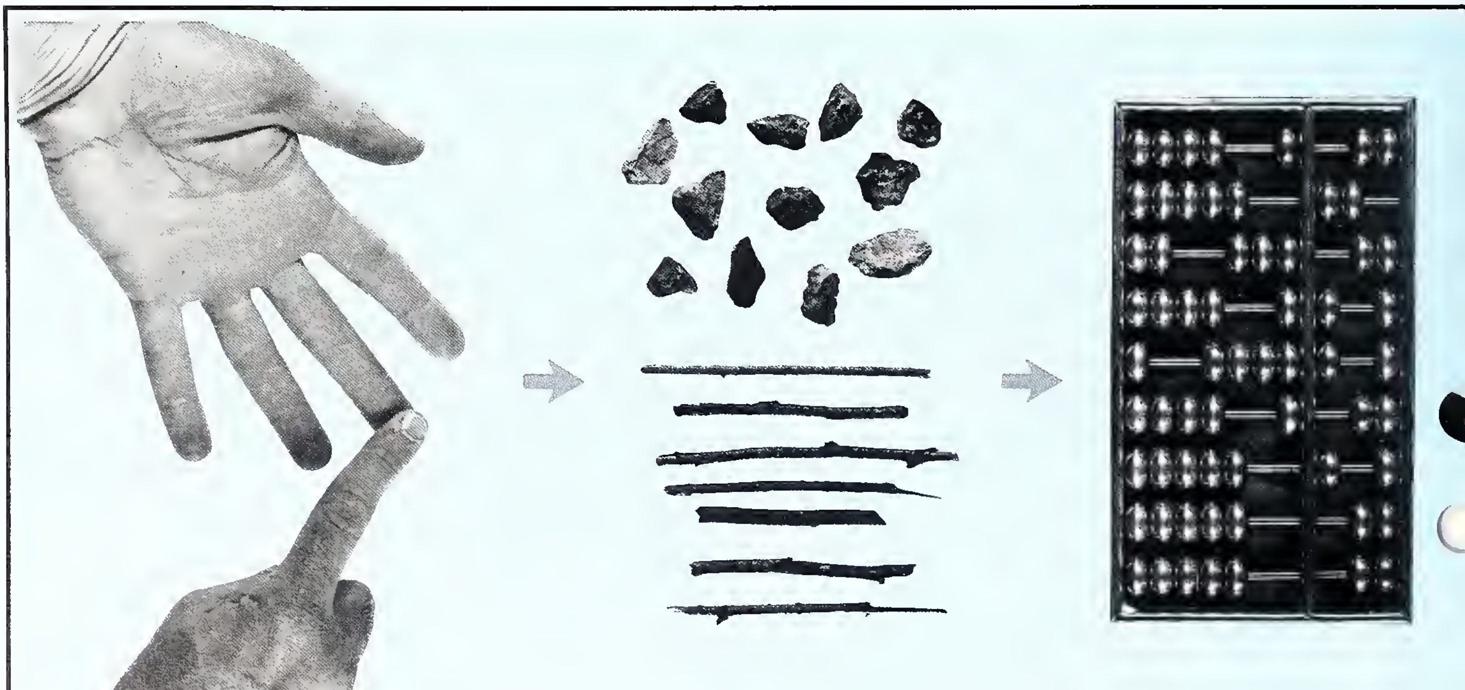
The human race has progressed through the ages of fire, stone, iron, machines, chemicals, and atoms. We are well into the age of biotechnology. But the era that will really revolutionize our lives is the age of information. As Mother Shipton, English prophetess of the 15th century, predicted, "thoughts will fly."

Before we explore some of the fascinating electronic developments that are shaping the current scene and reshaping our work and play environments, let us pause for a moment to reflect on the historic events and circumstances that brought us to this point. As the account in *National Geographic* tells us (vol. 168, no. 5, November 1985), the moment of discovery was like a time warp, propelling anthropologist Mary Leakey back through the eons until she stood on the shores of the primeval lake, in the shadow of the great volcano Sadiman. It seemed as if the couple had just passed, their bare feet making deep, clear impressions in the moist volcanic ash. She saw where they had paused, distracted, and then moved on. The message of their footprints, long since solidified into volcanic rock, was comprehended immediately by the famed anthropologist. It said, "We are human."

Whether or not the two were truly human would become a matter of controversy, but one fact would remain certain: these, our early ancestors, were bipeds. Because they walked upright, their hands were free to feel and grasp, to carry and shape objects, and, eventually, to wield them. All of their animal ancestors, from the simplest of life forms, had changed, evolving to adapt to their environment. All of their offspring, through the generations until modern times, would change and evolve to make better use of their tools. Upright stance, opposed thumbs, digital dexterity, and large cerebrums are unique characteristics of the great tool-maker, who, instead of adapting to environment, controls environment.

Through the ages, humans developed tools to extend the function of their limbs, muscles, and senses; to move faster, see farther, hear more acutely; in general, to get more leverage on the world. Along the way they invented a few thought tools — extensions not of muscle, but of mind. Now these thought tools, by far the most powerful of all, are revolutionizing human life. They will revolutionize agriculture.

The calculating machine. Starting with sticks and stones and their own fingers, human beings have constantly sought methods of calculation and computation. The first of



Over the years, humans have sought and developed various methods of computation.

the *digital* computers, the abacus, was invented independently by both the Greeks and the Chinese before the Christian era.

The most widely used *analog* computer — the slide rule — was invented in 1622 by English mathematician William Oughtred. In 1642, Blaise Pascal designed and built the first *mechanical* computer. During the 19th century, a number of mechanical calculators were developed. It was in this period that George Boole formulated the fundamental mathematical language of computers, now referred to as Boolean algebra. It was at this time, too, that the practice of using punched cards to preprogram and control machines was introduced.

The pace of computer development picked up in the 1900s, and in 1946, ENIAC (electronic numerical integrator and calculator), located at the University of Pennsylvania, became the world's first fully operational electronic digital computer. ENIAC, which weighed several tons, was patterned closely after a prototype designed and built at Iowa State University.

The scientific breakthrough that blazed the trail for the modern computer occurred in 1948 when John Bardeen and two of his co-workers at Bell Laboratories invented the transistor. This great invention must rank with the wheel, the steel plow, and the radio. It eventually permitted the computing capacity of earlier computers to be condensed into chips, each no larger than a fingernail.

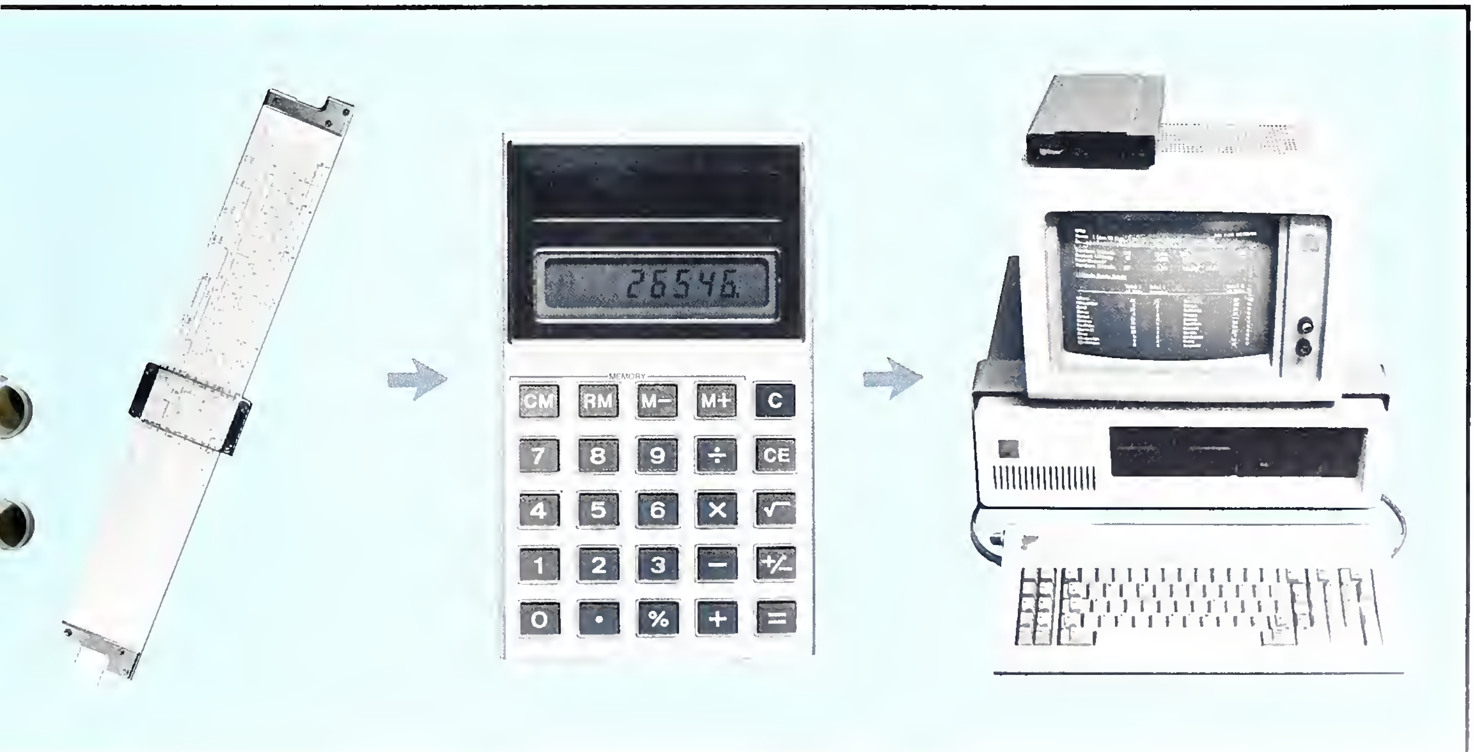
Shortly after the invention of the transistor, Bardeen became professor of physics at the University of Illinois. He later became the first person to win two Nobel prizes in the same subject area — one for the transistor and one for his pioneering work in superconductivity.

A love affair with speed. In February 1949, the Digital Computer Laboratory, later the Department of Computer Science, was organized at the University of Illinois. This department, which would become the mecca of computer design and development, has produced many computers in the last thirty-three years.

The ILLIAC (Illinois integrator and automatic computer), completed in 1952, was the first large electronic computer built and owned entirely by an educational institution. Since then, computer scientists at the University of Illinois have created ILLIACs II, III, and IV. ILLIAC II, which became operational in 1962, was one hundred times faster than ILLIAC I and ten times faster than any other computer in existence at that time.

ILLIAC III, a unique machine devoted to image analysis (pattern recognition) had tremendous potential. It opened the way for automated photographic analysis, aerial reconnaisance, remote multispectral sensing, and a host of tasks related to the storing and cataloging of printed matter. In pattern recognition lay the roots of machine "vision," machine "hearing" (voice recognition), machine "touch," communication between humans and computers via natural language, and internally controlled robots.

Computer scientists at the University of Illinois have always been enamored of speed and capacity, and rightfully so: extremely fast computers bring down the cost of computing and provide opportunities to solve important problems that are simply beyond the reach of scientists



without great computational resources. ILLIAC IV, designed in 1965, was intended to perform a billion operations per second. Had it been built on the day the design was completed, its data-processing capabilities would have equaled those of all the other experimental computers in the world combined. ILLIAC IV reigned as the fastest computer in the world until the recent advent of the supercomputer.

The relentless quest for speed continues even to the present. An article later in this issue describes the University of Illinois's pioneering thrust into the astounding world of supercomputing. David Kuck and his associates at the University's Center for Supercomputing Research and Development are embarked on another effort to design and construct the fastest computers in the world. The approach they are using is known as parallel processing. Powerful individual computers on chips are harnessed in parallel and programmed with unique and very complex software to accomplish several individual tasks simultaneously, such as computing and moving data to and from memory. The project that Kuck and his colleagues have designed could, along with other developments, increase the University's computing capacity a thousandfold over the next five years.

Historically, one of the strengths of our university's computer research and education program has been the balanced development of both hardware and software. Although most people think of computers in terms of hardware, software is just as or perhaps more important. Software contains the written instructions that tell computers how and when to manipulate numbers and symbols, how and where to read input information, and how and where to put the output of the computer operation.

The teaching machine. The first and by far the most widely used system for computer-assisted instruction was PLATO. Developed by Donald L. Bitzer, now director of the University's Computer-based Education Research Laboratory, PLATO was first demonstrated in 1960 at

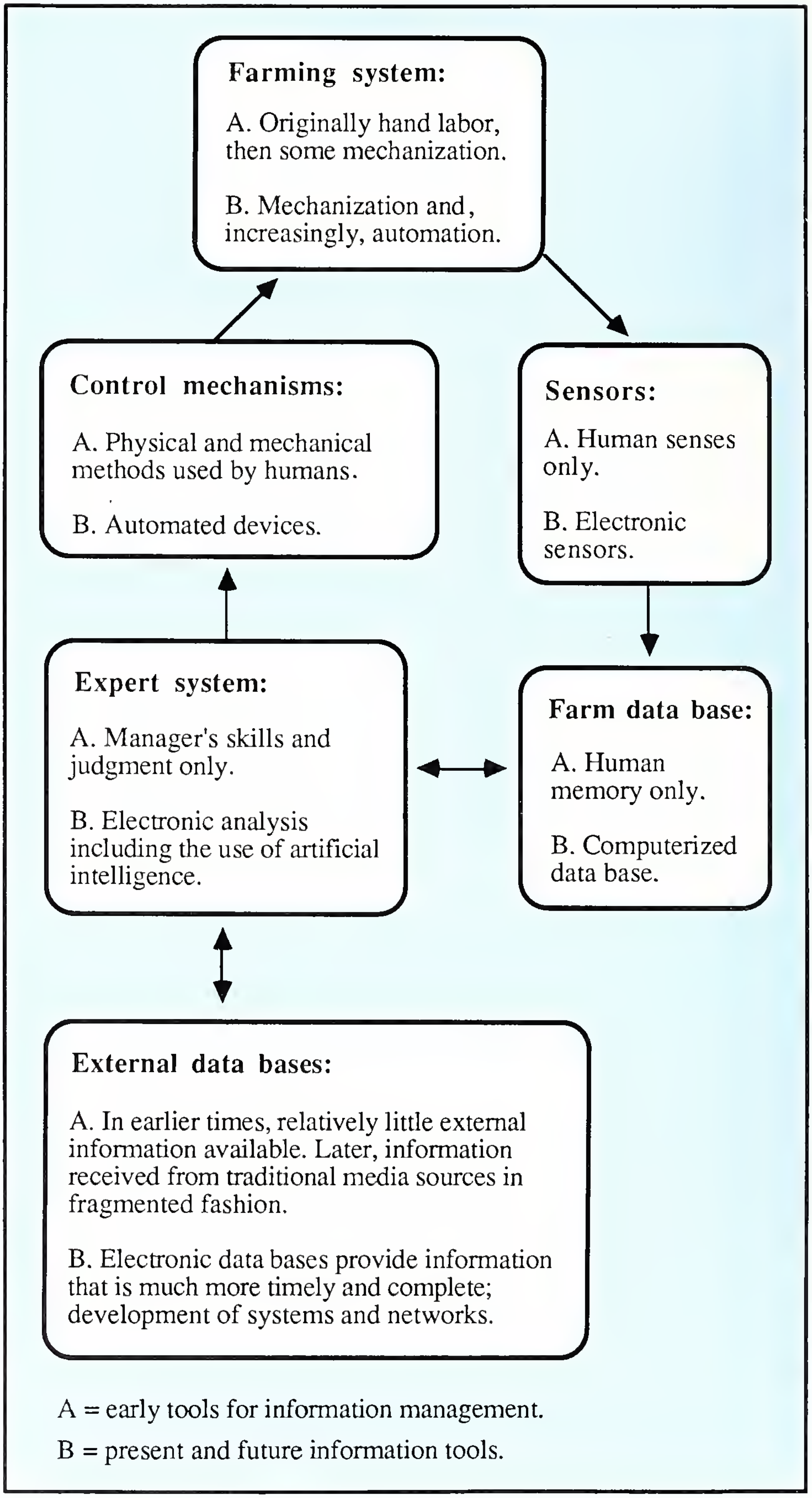


Fig. 1. A schematic representation of information flow in farming. Although the components in farming and their interrelationships remain the same, the quality of information changes as computers replace traditional sources.

the University of Illinois. The project, in which Control Data Corporation invested over $20 million, produced TUTOR, a computer language specifically designed for teaching via PLATO. TUTOR, coupled with the touch-sensitive plasma screen, makes PLATO a powerful teaching and learning tool.

Students are able to sit at a computer terminal and learn languages, music, physics, and other subjects. PLATO is continuing to expand, and 12,000 contact hours of instruction are available in more than 100 subject areas. PLATO networks are worldwide, reaching students in North America, Australia, Belgium, Denmark, Italy, Israel, Taiwan, South Korea, and other countries. The system has been demonstrated in the Soviet Union.

The thinking machine. The new science of artificial intelligence, pioneered by Stanford University, Carnegie-Mellon University, and the Massachusetts Institute of Technology, has also been the subject of research at the University of Illinois. The University's Artificial Intelligence Laboratory, headed by Ryszard S. Michalski, develops software that permits expert systems to be produced with common computer languages and relatively less expensive equipment.

Working closely with Michalski and Bruce Katz in the Artificial Intelligence Laboratory, Thomas W. Fermanian from the faculty of Horticulture has recently developed AgAssistant, the first expert system software designed specifically for agriculture. Fermanian's article later in this issue deals with the enormous potential that expert systems have in relation to agriculture.

The automated farm. In times past, the farmer used his senses of sight, hearing, and touch to gather information about the farming operation. This information, stored and processed in the farmer's brain, enabled the farmer to make and implement decisions with the help of brain and muscle. Over the past centuries, and particularly rapidly over the last century, machines have replaced much of the farmer's direct physical involvement in farm operations. Now, computers have begun to replace the farmer's direct mental involvement in the farm operation.

Machines reduce the need for the farmer to perform *physically* strenuous, tedious, and hazardous tasks. Computers reduce the need for the farmer to perform *mentally* tedious tasks, such as calculations and analyses. In addition, computers help the farmer perform these jobs more accurately and thoroughly.

Projecting into the future, one can envision a farm on which important information will be gathered by various electronic sensors. (See Fig. 1 for a schematic representation of the future farm operation.) Information will then be stored in spreadsheets and other data bases. Relevant information from other sources will be automatically collected from local, regional, national, and international data bases. The farmer will have access to this information through computer networks and various information retrieval systems.

At the heart of such an operation will be the expert management system. It will consist of a package of individual expert systems, each designed to make or help make a specific management decision. The overall function of this management system will probably be coordinated and sequenced by a controlling expert system with which the farmer will communicate in natural language, often simply using the spoken word. Just as machines are extensions of limbs and muscles, this expert management system will be a powerful extension of the farmer's mind.

On this farm of the future, the farmer will implement decisions made with the aid of computers; or decisions will be automatically implemented through electronically controlled machines and devices. Conventional farm machines, such as tractors, chisel plows, and combines, will be equipped with elaborate electronic controls and microprocessors that will guide, control, and adjust them.

In addition, exotic machines, such as robots, will perform intricate tasks very precisely, with little or no guidance from humans. Robots will be able to traverse uneven terrain; they will grasp and manipulate objects and organisms moving either in the wind or with their own power. These machines will operate twenty-four hours a day when needed, in cold and heat, dark and light, under wet and dry conditions.

The microprocessors of the future will have the enormous speed and memory of today's mainframe computers. Desktop computers will become the workstations from which human managers will control farms, agribusinesses, agricultural research, and educational activities. Minicomputers will be communications nodes, disseminating information on huge, highly integrated agricultural networks. At the top of this hierarchy will be the mighty supercomputers of the future, capable of analysis and prediction that are undreamed of today. The computer network will be as essential and commonplace as the telephone network today.

We have come a long way from the fateful hour at the dawn of humanity when our bipedal ancestors took their historic walk, leaving a message for us to read millions of years later. But, as it was for them, our journey is just beginning.

Donald A. Holt, director, Agricultural Experiment Station ☐

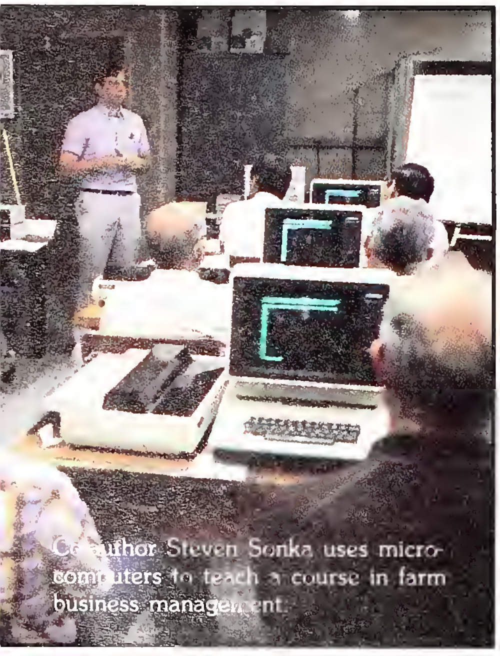
Computers in Agricultural Decision Making

Steven T. Sonka, Michael A. Hudson, and Raymond M. Leuthold

The 1970s and 1980s have been a period of profound change for American agriculture. After several years of rapid inflation and low real interest rates, the agricultural sector experienced in this period a sudden rise in interest rates, a decrease in incomes, and dramatic declines in asset values. Because of this turbulent environment, agricultural managers have become keenly interested in tools that can help them make effective decisions. The personal computer appears to be one such tool.

Computer-related technology has advanced very rapidly. Only ten years ago, it was not even commercially available. Today, however, microcomputers can be purchased for a few thousand dollars.

Although the potential for the new technology is promising, our recent experience has shown that effectively implementing the technology can be a challenging and difficult process. The purpose of this article is to consider the microcomputer's role in improving agricultural decision making. The contribution of management research and education in developing and enhancing this potential will also be discussed.



Co-author Steven Sonka uses microcomputers to teach a course in farm business management.

The current scene. Information is an essential element in decision making. The microcomputer has the potential to substantially increase in several ways the amount and types of information available to the decision maker. In this context, the computer's ability to perform complex calculations rapidly and accurately is the attribute that comes to mind most quickly.

A second major attribute is the capability to acquire, store, and retrieve substantial amounts of data from a variety of sources. Included in this benefit is the computer's ability to communicate electronically with other computers in order to acquire data.

A third feature is the computer's ability to generate text through word processing. Recently, major strides have been made that also allow microcomputers to generate graphics.

Some farm decision makers have already begun to use the small computer in their businesses. In 1982, a study by the Department of Agricultural Economics of "innovative" computer users indicated that financial accounting was the field in which the computer was most used. (The term *innovative* is used to describe those individuals regarded as effective users of business management techniques.) Maintaining physical production records and developing financial projections were the next in order of frequency of use. Although not common at that time, electronic acquistion of data was expected to become an increasingly important function in the future.

Over the last five years, steady advances have been made in the capacity and economic availability of microcomputer hardware. Similarly, the instructions needed to operate that hardware (commonly referred to as software or computer programs) have become increasingly sophisticated, unlocking the power contained in the technology.

Despite these continual technological advances, computer technology has been adopted and utilized more slowly than many had expected. There appear to be several likely causes for this situation. One important reason is the economic adversity faced by many industries and individuals during the 1980s. This adversity has, of course, been particularly severe in agriculture. Another reason is that users underestimated the difficulty they would experience with the new technology. It is now apparent that if this technology is to be used to its maximum potential, we must be able to use it to generate the specific information that is needed. For example, two individuals may be interested in purchasing farmland. One may be most concerned with the long-run profit potential of the purchase, whereas the other may be most concerned with the short-term financial risk. Use of the computer to evaluate the land purchase could be helpful to both individuals. However, the computer-generated information that each of these individuals needs is greatly different.

Decision making with computers. Although considerable microcomputer hardware and software are available for farmers and agribusiness managers, a major gap still exists between the total needs of decison makers and the technology's performance. The results of three recently completed research efforts, conducted within the Department of Agricultural Economics, illustrate this gap:

- Analysts studying crop production record needs discovered the limitations of software packages. The software allows users to monitor only a portion of the possible relevant factors. For example, only limited capabilities exist for monitoring weather

conditions or for producing results in a graphic form.

- An analysis of farm accounting needs indicated that users require a diverse range of information to manage their finances. These systems range from simple cash accounting to a system as complex as that needed by a large manufacturing firm.
- A similar diversity of needs was found among the Illinois pork producers who were surveyed. Interestingly enough, it was found that farm computer users who had adopted general-purpose programs, such as spreadsheets or data base management programs, tended to be more satisfied with their computer systems.

The specific results just cited illustrate a broader concept, that the use of the small computer to support management decision making is fundamentally different from the use of computer technology for data processing (Fig. 1). The latter involves the processing of relatively routine transactions to produce standardized reports, such as monthly cash-flow statements. An emerging concept — that of the *decision support system* — refers to the use of computers to directly assist decision makers. To date, the vast majority of the tasks to which the microcomputer has been applied in agriculture fit within the data-processing category. However, data-processing reports provide only part of the information needed by the agricultural decision maker. If computer programs were available to provide an effective decision support function, farmers would more readily adopt this technology. For example, a program that allows producers to test the effectiveness of the specific marketing strategies they are contemplating could have considerable value.

Research and educational needs. Because of the deficiency just noted, the need for management-related research and education is pressing, for these will contribute to the development and adoption of systems designed to help farmers make decisions. Although computers will play a crucial role, the emphasis will be on the needs and problems of the managers. We therefore need to develop a much better understanding of the processes by which human beings make decisions.

When working with actual problems, researchers have to seek information from several disciplines. Thus multidisciplinary, problem-focused research is likely to yield the highest returns. Because colleges of agriculture have a tradition of disseminating useful information, they should contribute actively to such research. An essential element in that contribution should be the production of *new* knowledge and *prototype* computer systems for agricultural use.

Understanding and using available technology to develop decision support systems will require focused educational programs. Colleges of agriculture will need increasingly to emphasize the computer as a tool that enhances decision making in management.

We are currently using this method in our teaching and research. The Department of Agricultural Economics has launched an exploratory project entitled, "A pilot investigation of the uses of microcomputer-based networks for business management and marketing simulation in agriculture." This effort will explore and implement the use of microcomputers to teach business management concepts in existing and planned undergraduate courses. The hardware support for this project is being provided as part of the University EXCEL project funded by the IBM corporation.

Steven T. Sonka, professor, Michael A. Hudson, assistant professor, and Raymond M. Leuthold, professor, Department of Agricultural Economics □

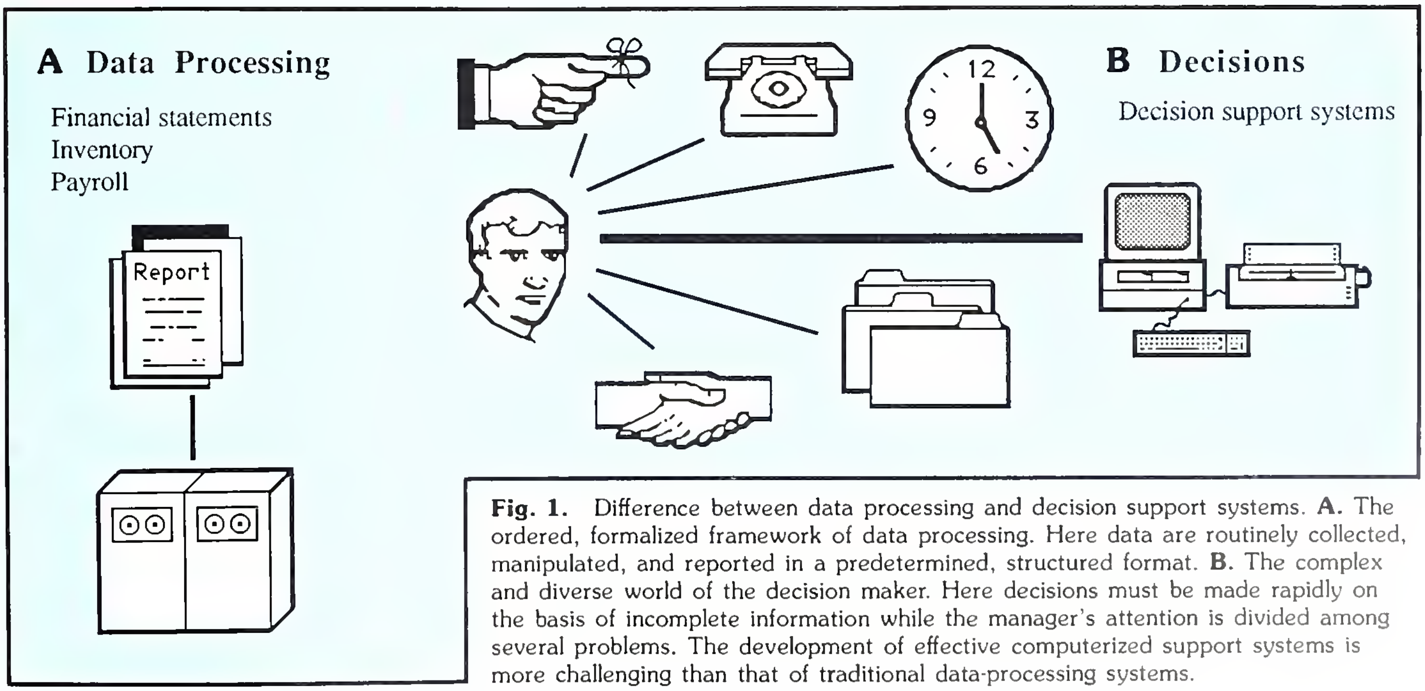


Fig. 1. Difference between data processing and decision support systems. **A.** The ordered, formalized framework of data processing. Here data are routinely collected, manipulated, and reported in a predetermined, structured format. **B.** The complex and diverse world of the decision maker. Here decisions must be made rapidly on the basis of incomplete information while the manager's attention is divided among several problems. The development of effective computerized support systems is more challenging than that of traditional data-processing systems.

Can the Supercomputer Cure the Common Cold?

Michael Grossman

Although the supercomputer can't cure the common cold yet, it can support research that may one day help to find that cure. A recent research article from Purdue University reported that biologists there used the supercomputer to piece together about 6 million bits of information to map the three-dimensional structure of the virus that causes the common cold.

The term *supercomputer* refers to the most powerful computer available at a given time. The power of a computer is measured by the speed with which it processes information, its storage capacity or memory, and its precision. At the University of Illinois, we have not one but two supercomputers. A CRAY X-MP is located at the University's National Center for Supercomputing Applications, directed by Larry L. Smarr, and another is under construction at the Center for Supercomputing Research and Development, headed by David J. Kuck. Both computers are heavily funded by federal and state sources. As the home of two major centers for supercomputing research and applications, the University of Illinois is unique among land-grant universities, providing a special opportunity for agricultural scientists to apply supercomputing to agriculture.

The United States has maintained its leadership in science, technology, and agriculture largely because of strides made in computer technology. Within the agricultural sciences, several disciplines have discovered the value of large-scale computer simulations. In fact, simulations are used by the animal sciences in breeding and genetics; by agricultural engineering and soil sciences in three-dimensional soil dynamics; by agronomy in large-area production forecasting; and by agricultural economics in formulating optimum production practices.

The largest and fastest computers — the supercomputers — are being used to explore the basic laws of nature and also to simulate complex agricultural problems. Because supercomputers enormously extend the range of problems that are effectively solvable, they provide scientists with many new insights.

Animal research. To give a brief description of the types of problems that may be solved with the supercomputer, let's begin with animal breeding and genetics. In animal sciences, researchers are investigating methods for estimating genetic parameters to predict the performance of an animal. For example, to genetically evaluate dairy sires used in artificial breeding programs, a method was developed, known as "best linear unbiased prediction." The method, used worldwide, could be extended to predict more than one trait with the help of the supercomputer.

For an accurate evaluation, all available data are incorporated into the computations, which then require that large systems of equations be solved. For example, to evaluate the genetic transmitting ability of sires from all cows in the testing program, perhaps as many as several million equations must be solved simultaneously. The effective use of current and new theoretical developments in animal breeding and genetics, therefore, requires the use of faster and more efficient algorithms — the step-by-step procedures consisting of mathematical and logical operations necessary for solving a problem. These algorithms are designed for a faster and more efficient computer, such as the supercomputer.

Soils research. The supercomputer can be applied elsewhere in agriculture. In soil dynamics, researchers from agricultural engineering can construct, test, and choose from among models that show the interactions of tillage tools with soil. In one type of model — the finite element model — forces and soil displacements that are generated as the tillage tool moves through the soil can be simulated. The model could be greatly improved by the supercomputer's ability to work with billions of observations and to produce three-dimensional graphics. The tested models can be visualized more easily through these graphics. Some of the goals of soil dynamics research are to reduce the energy spent in tillage, improve traction, reduce soil compaction, and decrease soil erosion on farmland.

In agronomy, soils research would give users access to a large data base containing farm management records and details on weather and soil characteristics. The supercomputer would serve a valuable function in recomputing, revising, and updating the estimated productivity indexes for Illinois soils. This would be a formidable task without a computer, as there are over 500 soil types in Illinois.

Economic models. The supercomputer will allow us to develop more nearly complete, realistic models to understand better the world around us. The information thus derived could be used by researchers in agricultural economics. Each model would be specific to a situation, reflecting a farm with differing soil types and multiple crops. The model would account for timing, machinery, and credit constraints. If more activities were added to the model, so as to reflect reality better,

the size of the model would increase geometrically. The supercomputer is capable of analyzing statistical models with several hundreds, or perhaps even thousands, of variables.

Forecasting. The supercomputer can affect world agriculture through forecasting large-area production. Models can be developed that predict crop status for regions and nations. Part of the information required as input for these models will come from satellites. Multispectral sensors in the satellites capture enormous amounts of data, which are beamed back to earth with each pass of the satellite.

It is commonly accepted that weather causes most of the year-to-year variation in average crop yields. Weather, therefore, provides important input for forecasting models. Great computational capacity is required to analyze weather information and to asses the weather's impact on crop yields.

The commercial value of the information generated by large-area production forecasting is proportional to the timeliness of the information. The supercomputer offers scientists the opportunity to process data and generate predictions rapidly. This information can then be quickly disseminated via computer networks to interested persons.

Stochastic dynamic simulation. The supercomputer will add an important dimension to agricultural simulation by permitting the techniques of stochastic simulation to be applied widely. The term *stochastic* refers to a statistical representation of numbers based on probability distributions. In stochastic models, the concept of randomness is introduced into the predictions. The models yield not only an estimate of a price or a quantity, but also a level of confidence that the user places in that estimate. This element is very important in agricultural planning.

In the past, nonstochastic (deterministic) models have been used, employing an extremely simple system with few variables. These models do not provide estimates of error associated with the predictions. The prediction, moreover, consists of a single numerical value. For example, a deterministic production model can provide a numerical estimate of yield, say 130 bushels per acre. But it does not give an estimate of the precision of this prediction. A stochastic model, on the other hand, provides some measure of the confidence that you can place in the prediction. Thus, if you are planning to purchase corn futures, you might respond differently to a yield prediction of 130 bushels plus or minus 5 bushels than of 130 bushels plus or minus 25 bushels per acre.

In the real world, there are many systems with many variables. As variables are added to the models to make them more representative of the real world, the computational requirements become astronomical. The resulting situation has been called "the curse of dimensionality." With the help of the supercomputer, scientists will be able to deal much more effectively with the theoretical and practical problems related to decision making.

Power of the supercomputer. Because of the enormous number of computations involved, many applications of the computer are not implemented. A major advantage of the supercomputer is the speed with which it allows a researcher to go through several cycles of computation within a short period. Algorithm development requires many trial runs. Because these runs only take a few minutes on the supercomputer, one can get through a great many trial runs per day.

According to benchmark figures supplied by Cray researchers, two minutes of computing on the supercomputer CRAY X-MP are equivalent to about one week of "number crunching" on a fast personal computer and about four and a half months on an ordinary personal computer. In other words, the Illinois supercomputer is about 5,000 times faster than the personal computer with a coprocessor, and about 100,000 times faster than the one without. Clearly, the supercomputer can increase scientific productivity enormously.

Locations of supercomputers. The two most widely available supercomputers are the CRAY-1 and the CYBER 205. These supercomputers and others are being used throughout the world; they are located at national laboratories, in industries, and at universities.

In August 1985, the University of Illinois's National Center for Supercomputing Applications acquired a more powerful supercomputer — the CRAY X-MP/24. This model has two processors, 4 million words of memory, and a 32-million word solid state disk. It is equivalent to about 5 CRAY-1 computers. When upgraded over a five-year period, the supercomputer should have a capability that is 50 to 100 times that of the CRAY-1.

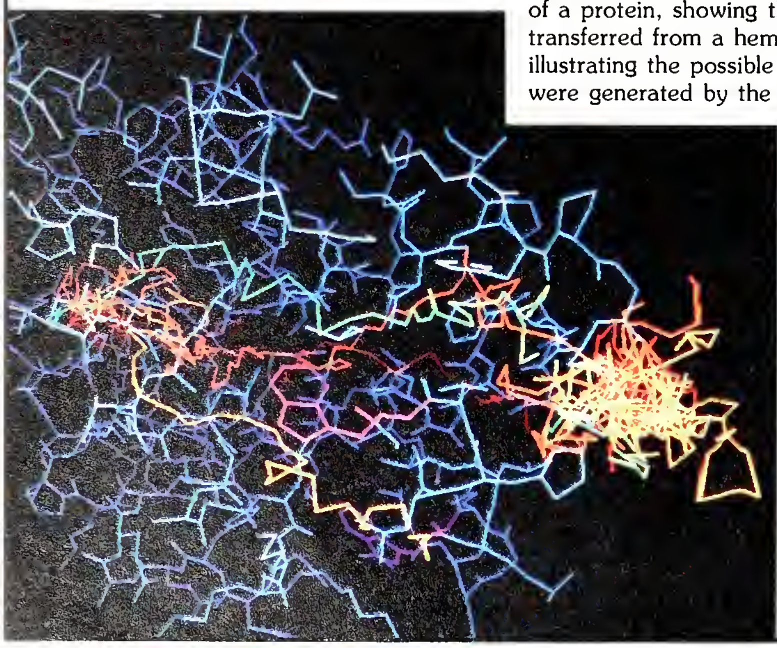
Computing costs. The supercomputers at American universities, although a welcome arrival, have had less immediate impact than expected because the researcher must obtain a grant to pay for the very high cost of computer time. For example, users of the CRAY-1 or the CYBER 205 may pay as much as $1,000 per machine hour.

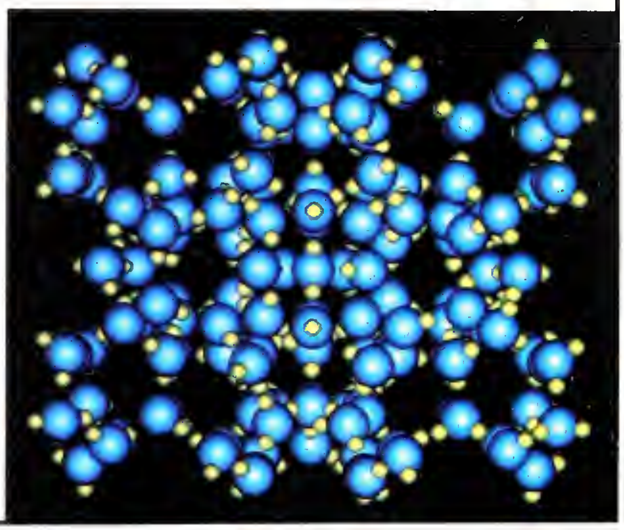
Thus a significant agricultural research project requiring even 25 to 50 hours per year, will be prohibitively expensive to agricultural scientists. As a result, many of them avoid undertaking research that will involve use of the supercomputer. There is, consequently, a critical shortage of agricultural scientists competent in those fields that require numerical research. At the moment, few facilities exist to train future agricultural researchers in supercomputing.

Meeting the challenge. Colleges of agriculture must provide a new type of research facility — one that represents the state of the art in both the supercomputer and its associated support equipment. With the supercomputer as a magnet, the facility will attract and encourage the top minds in the agricultural sciences to interact with scientists in supercomputing so that new techniques can be developed for solving previously intractable problems in agriculture.

Located at the National Center for Supercomputing Applications, the CRAY X-MP/24 (above) is the most current of supercomputers. It has two central processing units and is at the center of an integrated system.

The qualities of the supercomputer that first come to mind are its incredible speed and number-crunching capabilities. However, its graphic capabilities (below) are also extraordinary. Visual representation of the supercomputer's enormous numerical output is, in fact, a necessity. On the left is a representation of a protein, showing the possible paths that electrons might take while being transferred from a heme to another group. On the right is an ice sample illustrating the possible structure of amorphous ice crystals. (Both graphics were generated by the Wolynes research group, School of Chemical Sciences.)





Photographs courtesy of News Bureau, Office of Public Affairs.

It is often argued that the supercomputer crisis could be resolved if a few more machines were placed in national laboratories and if all scientists in American universities had access to the machines remotely. Although partially successful models for such a situation are available, one must consider the limitations, which are serious. These facilities serve specific disciplines, whose researchers are already in touch with each other. In contrast, major university programs centered around local systems would enable otherwise isolated agricultural scientists from many fields to share and learn from one another. The ensuing "eyeball-to-eyeball" cross-disciplinary interaction would probably not occur if a site were located remotely. Another advantage of a local supercomputer is that graduate students would receive a more up-to-date training.

The supercomputer at Purdue University was partially credited with the breakthrough in mapping the common cold virus. The researcher heading the project believes that if the university had not had the CYBER 205, the final calculations might have taken as long as ten years. With the supercomputer these calculations were made in about one month.

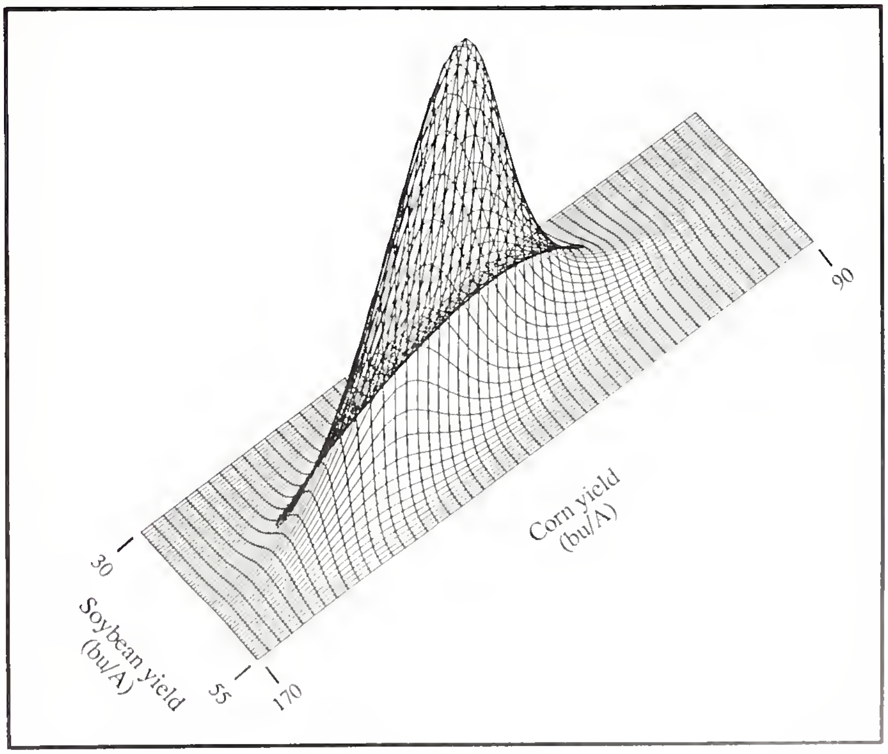
A proposed breakthrough. We have proposed establishing an integrated supercomputer facility, a Center for Applications of Supercomputing to Agriculture, at the University of Illinois. Given the strong graduate research programs in agriculture and computer science, such a facility, which would be interdisciplinary, would have an enormous impact in many areas of agriculture.

By offering users its potential power, the supercomputer shapes the aspirations of the human mind and redefines the limits of the possible and impossible.

Michael Grossman, professor of genetics □

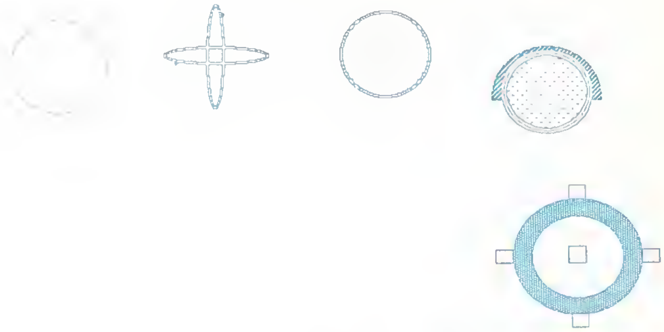
Three-dimensional graphics

C. Robert Taylor, professor of agricultural economics, uses his personal computer to generate three-dimensional graphics. He has a joint appointment with the University's National Center for Supercomputing Applications. Computer graphics can be used effectively in agriculture — to analyze yields, effects of agricultural programs on farm income, prices, and other factors. Instead of lengthy printouts, users are offered a visual representation that they can interpret quickly and easily. The graphic generated here illustrates the joint probability density function for corn and soybean yields in Champaign County.



Windmills in the Mind: Computer-Aided Design

Michael P. Sherman



The birth of the transistor in 1948 ushered in the computer age, which has continued to change our lives with each new discovery. Although by the 1970s computers were widely in use, it was not until 1981 that the first Computer Aided Design and Drafting (CAD) program was made available for the Apple microcomputer. In early 1982, I founded the Interior Design Computer Aided Design Teaching and Research Laboratory (IDCADLab) at the University of Illinois and became its director. The goal of the IDCADLab was to examine methods for developing and integrating CAD concepts into an already established design curriculum in the School of Human Resources and Family Studies.

At the IDCADLab, a wide variety of design-related issues have been researched — guidelines for other IDCADLabs, the best method of teaching CAD, applications for various industries, and use of a video camera interfaced with a computer as a design tool. The program offers opportunities for both instruction and research.

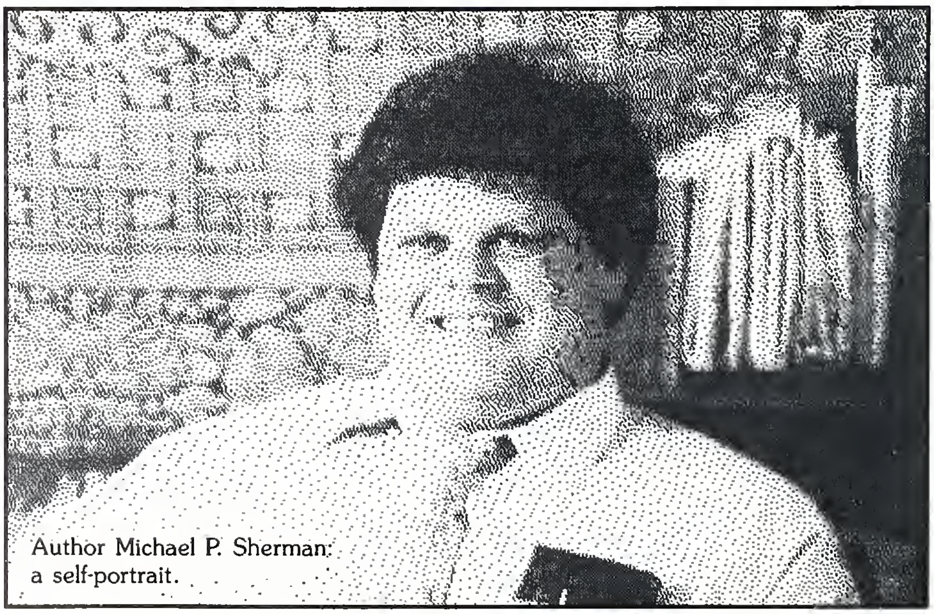
The laboratory is being structured to provide students with various hardware and software combinations. For example, Apple microcomputers and IBM micro- and minicomputers are set up with monochrome and color monitors having low and medium resolution. In one course a specific CAD program is taught while another is available for experimentation. Thus, students learn one program and transfer the knowledge to another. Students also learn to manipulate various devices for entering designs into the computer. They experiment with the digitizer (an electronic tablet for determining X,Y coordinates), using it in combination with a pointer — which could be a hipad, a stylus, a mouse, or a light pen. Ultimately, the various systems will allow the student to understand the similarities and differences between programs, CPUs (central processing units), and peripherals.

In the near future we expect that three-dimensional CAD programs will be available for the IDCADLab. Such a program mimics the designer's thought process in solving design problems and in visualizing situations three-dimensionally — by use of the coordinates of length, width, and height (X,Y,Z). The transitional but necessary step of assigning X and Y coordinates to develop "blueprints" can be carried out by the computer. Redundant and tedious drafting tasks are performed by the computer in a tireless fashion.

The IDCADLab has shown that CAD can be successfully taught and integrated into a design curriculum. However, much depends on the following variables: the availability of equipment; continued support for operations; dedication by faculty to keep up-to-date with the new software; and finally, the understanding and support of the administration.

The applications of CAD in the real world are limited only by the curiosity of the designer and an understanding of the whole system. When asked to explain if CAD is confining as a design tool, I say: "A circle can be an atom, a bubble, a chair, a gear, a windmill, a spacecraft . . . ."

Michael P. Sherman, assistant professor of interior design ☐



Author Michael P. Sherman: a self-portrait.

Data Bases for Agriculture

Martha E. Williams

More than 3,000 data bases containing numeric data, textual information, graphic data, or bibliographic references are available to the public, and 428 of these data bases are relevant to agriculture. Agricultural data bases of interest to researchers as well as other agricultural users cover such varied topics as U.S. cash grain prices, world livestock and poultry, chemicals in feral and food animals, climate, coffee, commodities, cooking, demography, extension, exchange rates, fertilizers, forestry, finance, futures, investment, import/export, interest rates, land use, law, leisure, loans, pests, pollution, potatoes, and weather — to mention a few.

The general public has access to the data bases through a variety of online services, and you require only a personal computer or a terminal coupled with a modem to find the information you want. You are no longer dependent on the local library. The data base you need may be hundreds or thousands of miles away, but if it is within telephone reach, it is accessible.

Data bases have grown by leaps and bounds in the last ten years. As indicated by the subjects mentioned earlier, virtually any topic of agricultural interest is within the scope of some data base. In 1975, there were only about 300 data bases. Today, there are 3,000. The number of records in those data bases has grown exponentially from some 50 million to more than 1.5 billion.

Although about 400 online services are available throughout the world, users can generally satisfy all their needs by using only 3 or 4 online systems, such as DIALOG or CompuServe and perhaps 6 or 7 files (data bases) on those systems. "Supermarket" information systems provide the user with data bases from which to get information. For example, researchers and others interested in agriculture will turn to DIALOG. Through DIALOG they will reach more than 200 data bases, including AGRICOLA (the National Agricultural Library's data base), Agricultural Economics, Commonwealth Agricultural Bureaux Abstracts, and Nutrition Abstracts.

A similar service is provided by BRS Information Technologies, which contains about 75 data bases. For those concerned with human resources and family studies, for example, the BRS includes Family Resources Abstracts, Food and Nutrition, and Inventory of Marriage and the Family.

A third data base supermarket is System Development Corporation, through which one can have access to Pesticidal Literature Documentation, Veterinary Literature Documentation, and Waterlit (water-related information) from over 100 files.

For nonbibliographic information, that is, information other than that found in journals and books, the user can again go to electronic files. A computer service is available for each area of investigation and provides a data base and software for manipulating the data. For example, Boeing Computer Services Company provides consumer and price indexes in electronic form. Chase Econometrics has dozens of Canadian and U.S. data bases, such as Canadian Agriculture, Fertilizer Forecast, and World Agriculture Supply and Disposition. Questions of consumer interest are answered by CompuServe.

Although the number of data bases and systems for searching them may be intimidating, these sources are, in fact, easy to use. Front end and gateway services allow easy access to electronic information. *Front end* refers to a software package for simplifying access to an electronic information service. A *gateway* service is a single service providing unified access to multiple online information services. A growing number of professionals who are not information specialists are using these services.

The front ends and gateways simplify procedures and are thus user friendly. For example, gateway users do not need multiple phone numbers, passwords, and protocols to gain access to multiple systems. Other advances in electronics, such as the development of artificial intelligence and expert systems, in particular, will contribute to the effort to improve access to data bases. And even more user friendly systems are on the way!

Martha E. Williams, professor of information science □

Joining the electronic circuit

The Office of Agricultural Communications and Extension Education (OACEE) is electronically delivering news from the College of Agriculture through the online AgriData Network, the largest agriculturally oriented information service in the country. Those users who have access to AgriData Resources (formerly AgriStar) can also have access to University of Illinois news by entering the report code: SNEWS.IL.

OACEE allows newspaper farm editors and others to receive news from the College of Agriculture via a minicomputer located on campus. Negotiations are under way to establish a more complete computerized information delivery service later this year for a more diverse clientele.

OACEE also offers online, direct news transmission to newspapers across the state. Through this effort, the College of Agriculture can deliver news three to four days earlier than via conventional mail.

In addition to making news from the College of Agriculture available electronically, OACEE downloads information from the AgriData Network and the Cooperative Systems Information, making it available for College administrators, agricultural communications students, and OACEE staff. This daily service includes a synopsis of agricultural news from major U.S. papers and all USDA news stories of interest in the Midwest.

Courtesy of Marilyn Upah-Bant, Office of Agricultural Communications and Extension Education.

Expert Systems for Production Agriculture

Thomas W. Fermanian

Production agriculture in the United States is generally a complex operation. Whether the operation is concerned with food and fiber (for example, corn, cotton, or vegetable production) or with a pleasing, functional environment (establishment and maintenance of a park or sports field), certain complex interactions are involved. A crop manager must be sensitive to changes in the environment because these changes affect the crop being produced or the facility being maintained.

Agricultural knowledge. Over the past several hundred years, farmers and agricultural scientists have developed tools and techniques to help control and respond to environmental pressures. Although the result of this response is generally a direct cultural procedure, such as irrigation, tillage, mowing, or pest control, many decisions must be made along the way to select the correct combination of techniques or tools necessary for success. Much of the knowledge needed to make these important decisions is simply developed on the farm through the accumulated experience of the manager.

Information, however, is also developed by researchers at universities and by industry. This body of knowledge, too immense to be stored easily for use by any one manager, generally relates to a past, specific instance and is often not directly applicable to the more general situation at hand. A production manager, therefore, must search this large knowledge base each time a question arises.

The process of collecting information and searching for the appropriate answer can be extremely time-consuming and laborious. It can therefore slow down a smooth crop-production operation.

If agricultural knowledge were stored in an organized way and facilities were available to search and retrieve pertinent information rapidly, management would become tremendously efficient. A practical but partial attempt to improve efficiency has been made through the dissemination of printed materials.

Knowledge, however, is more than simple written information, and it can be divided into two basic components. Written information is the component most often recognized by the agricultural community. This material, which refers to all types of printed matter, is *public* information.

Equally important, however, is the second component of knowledge: that which is *private* or *heuristic*. This is the knowledge of experience, developed and held by each individual. Heuristic knowledge represents the working rules of thumb or commonsense principles that an expert applies when searching for a solution. Heuristic knowledge is usually not formalized and is generally not published in any written form. It does, however, play an important role in problem solving. Knowledge is the total sum of facts plus heuristics.

Although human experts have the knowledge necessary for searching and evaluating agricultural information, they are not always readily available to production managers, specially at short notice. In addition, human experts generally focus on one particular segment of agriculture. Agricultural production, however, requires knowledge in many areas, generally beyond the scope of any one human expert. Machines can substitute for human expertise if the knowledge they communicate combines both heuristic and written knowledge.

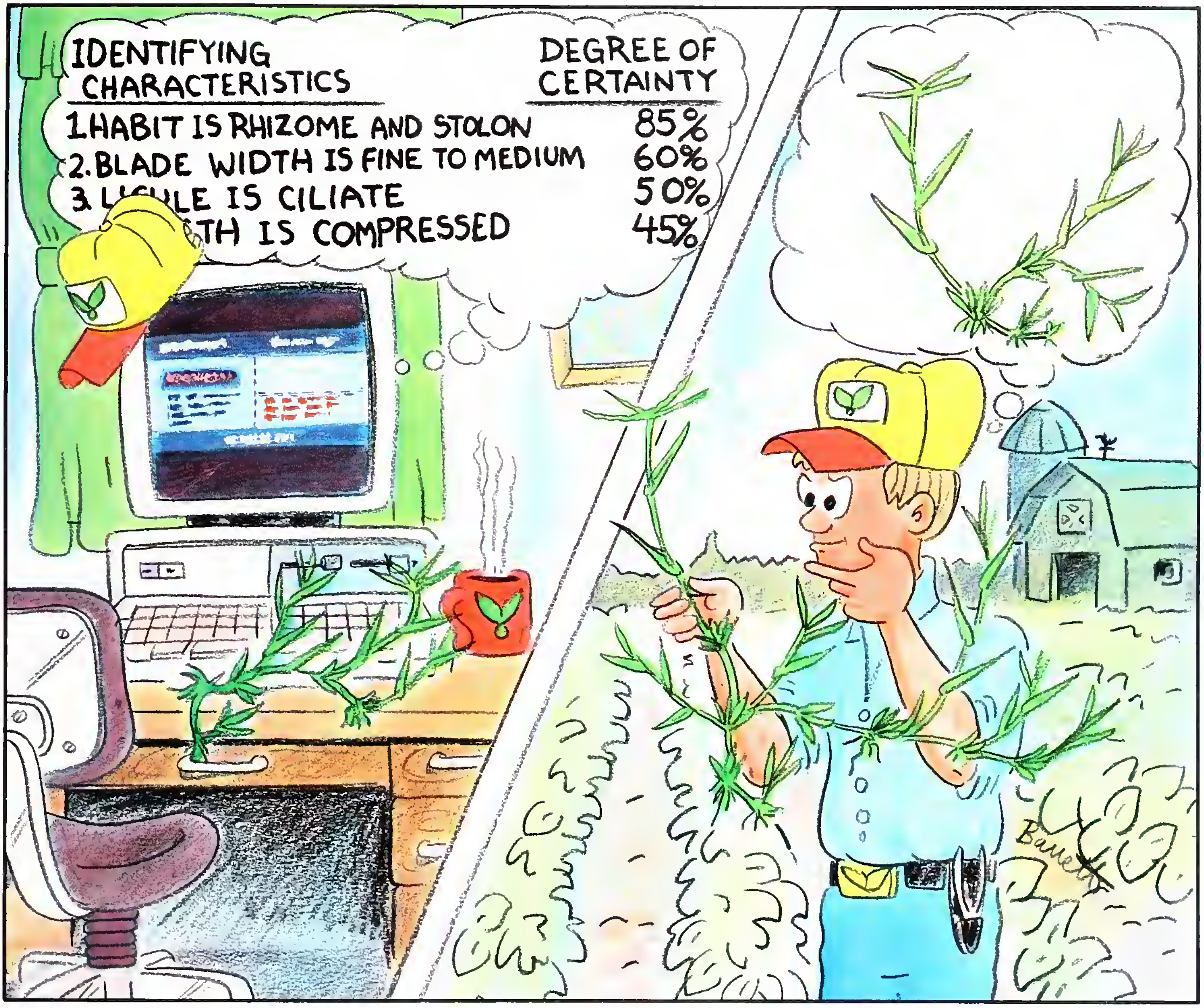
Artificial intelligence. Advances in computer technology might provide a solution for agricultural production managers. The science of artificial intelligence (AI), which was first developed in the mid-50s, is concerned with programming computers so that they can function like human beings. Research is currently being conducted in several distinct areas, one of which is sensory perception. Machine vision, voice recognition, and the computer's other sensory perceptions are being investigated.

Mechanical movement, or the science of robotics, is also within the scope of artificial intelligence. An area that shows great promise is that called computer-based knowledge systems. The systems search a base of pertinent knowledge for appropriate solutions just as human experts do. Hence the name *expert systems* (ES). Production managers using expert systems can retrieve the knowledge they need to make a decision. The expert system being consulted asks the user for the goal or solution to be achieved. Often this goal is deduced from the information provided to the system when the user answers prompted questions. The computer then searches the knowledge base for segments of information that will help the user reach the goal.

Expert systems at the University of Illinois. Work on expert systems at the University of Illinois began in the early 1970s. ADVISE, a meta-expert system (one that could be used to develop additional expert systems), was constructed on the campus's mainframe computer. Agricultural experts quickly concluded that in order for an ADVISE-based expert system to be of value in the field, it would have to be portable and capable of being updated easily with new information.

Diagnosis of diseased soybean plants. In 1976, the Intelligence Systems Group at the University of Illinois, in cooperation with the Department of Plant Pathology, began to design an expert system to diagnose diseased soybean plants. (The Intelligence Systems Group consists of scientists and graduate students who investigate new techniques for developing expert systems.)

One goal of these researchers was to transfer the final expert system to a small, portable microcomputer. They completed this task in 1982 by successfully adapting (downloading) the expert system PLANT/ds to an



IBM personal computer. One of the limitations of the system was that corrections or additions to the knowledge base had to be made on a mainframe computer and then downloaded to a new version of PLANT/ds. This method, of course, severely hampered agricultural experts, who could not modify the system while in the field. Thus, an expert discovering a new disease symptom could not add it to the system without going back to the mainframe computer.

The purpose of PLANT/ds is to identify soybean plant diseases specifically on the basis of their symptoms. More than 17 diseases were included in the data, and the symptoms described were matched with the most likely disease. A user was given multiple-choice questions pertaining to visible symptoms of the diseased plant.

On completing each questionnaire on the screen, the user was given a new list of questions that expanded on the previous answers. Each set of answers narrowed the potential number of diseases. When the search was narrowed to only a few answers, or often a single answer, the system suggested a disease. In an evaluation of the system's performance with over 300 unknown diseased soybean plants, PLANT/ds was able to provide the correct answer over 90 percent of the time. Thus the performance level generally could match the level of human accuracy.

Although PLANT/ds was extremely effective in diagnosing unknown soybean diseases in Illinois, it did have some limitations. Acquiring new information for the knowledge base was very time-consuming and laborious. The process required a computer scientist designated as a "knowledge engineer" to interview the plant pathologist, the "domain expert," to extract the information characterizing one disease and differentiating it from another. Long hours were spent in trying to formulate rules that would fulfill this purpose. In fact, the time required to build a new knowledge base was often too

long to justify the final use of the new system.

The inductive process. A new method of building a knowledge base was therefore necessary to help speed up and simplify the process. Researchers from the Intelligence Systems Group developed a system that could learn rules from specific examples of expert decisions. A new knowledge base was added to PLANT/ds, utilizing rules developed through this inductive process. In an experiment evaluating the relative performance of inductive rules and expert-derived rules, researchers found that inductive rules were more accurate than expert-derived rules.

Current research in expert systems. We are currently developing AgAssistant, a *microcomputer-based* expert system development tool with the capacity to develop and manipulate individual expert systems. Turfgrass weed identification was the first subject area explored with AgAssistant through the expert system, WEED.

AgAssistant is a unique program that attempts to capture all the capabilities of a full-fledged expert system within a microcomputer. It is based upon the highly successful ADVISE meta-expert system (Fig. 1). Among its advanced features are the ability to easily add and modify rules in its knowledge base, to create rules from examples, and to test the performance of user-created rules as well as their consistency and completeness (Fig. 2).

The rule base consists of groups of plant characteristics organized by their function (Fig. 3). It is evident from Figure 3 that a rule exists defining two sets of conditions that lead to the conclusion that the weed under consideration is bermudagrass. If either set of conditions — in this case 6 vegetative and 5 floral — is met, then the weed is identified as bermudagrass. While the rule is in essence complex, it takes the general form:

If ***condition****, then* ***decision****.*

The condition denotes or represents one or more elementary conditions, each with an associated weight or degree of certainty. The condition can be a complex of elementary conditions — such as all of the vegetative conditions. It is defined as *conjunction* and denoted by AND. Or the condition can consist of two or more complexes of elementary conditions — such as those found in the bermudagrass rule with both vegetative and floral conditions. It is then defined as *disjunction* and denoted by OR.

The user is also provided with a program that makes it easy to enter in examples of expert decisions. The purpose of these examples is twofold: first, they allow the user to create rules from them, using the algorithm GEM (generalizations of examples by machine) to distill the specific examples into more general examples or rules. GEM does this by searching the examples for similarities and using those similarities to produce new general rules. Second, the examples provide a set of events to test the user's rules. For example, if a specific feature of grass is identified in a number of examples as being typical of bermudagrass, the feature is incorporated into the bermudagrass rule.

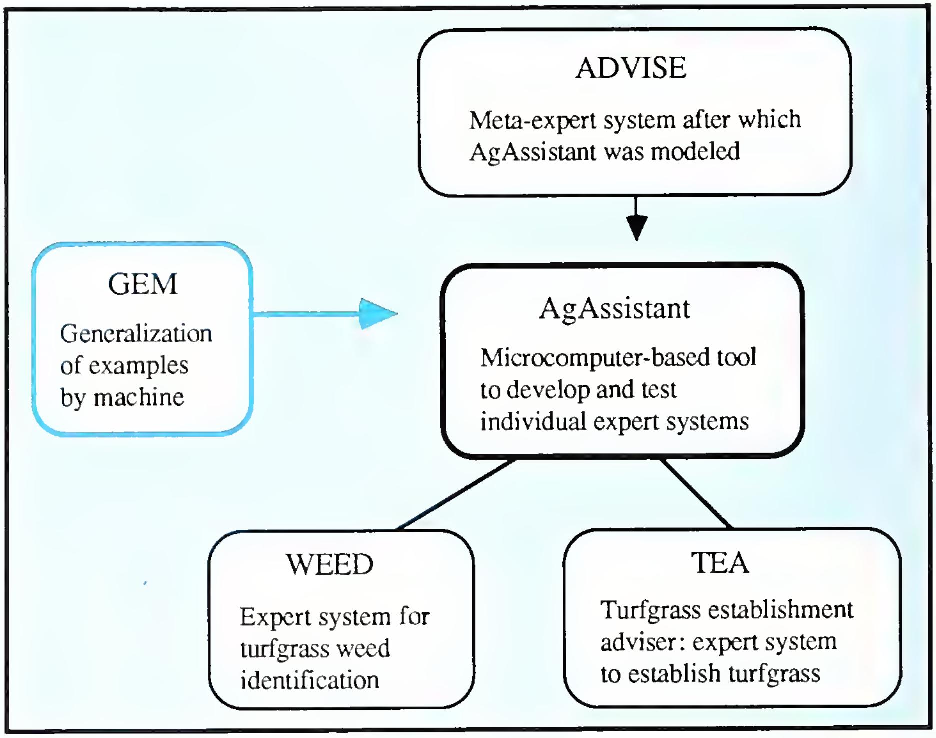


Fig. 1. Interrelationship of specific expert systems relevant to turfgrass management.

The user can get advice from the rule base, which may contain induced rules, user-supplied rules, or a combination of both. The user is asked a series of questions to determine which of the various rules in the knowledge base are best supported by the chosen answers. Additional questions are asked until all rules have either been confirmed or rejected.

Additional expert systems are also being developed with the help of AgAssistant. We are constructing a system to help establish turfs — TEA (turfgrass establishment assistant). To appreciate fully the response of turfgrass varieties to various environmental conditions, we are using GEM to induce rules. These rules will be based on the performance of turfgrass varieties throughout the United States. The potential benefit of TEA will be to provide a list of the adapted varieties of turgrass for a specific environmental condition. This finer adaptation will help to grow excellent turf with a minimum of energy and material resources.

Future directions. The future of expert systems as a tool for agricultural managers is exciting even

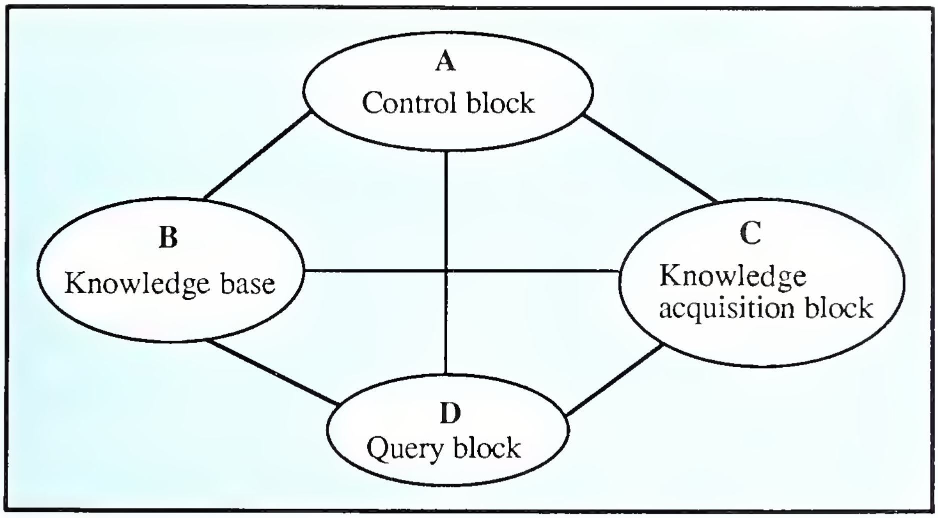


Fig. 2. A schematic representation of AgAssistant. Unlike previous computer programs, AgAssistant along with other expert systems development programs separates the knowledge needed to make decisions from the decision-making processes. This separation simplifies the process of updating or correcting the information in the knowledge base. The modular arrangement facilitates the rapid construction of new expert systems by allowing the user to add new knowledge to the knowledge base without changing the total program. AgAssistant consists of four components: **A.** The *control block* contains a set of menus (choices) that allows the user to move easily within the whole system. **B.** The *knowledge base* consists of two parts: (1) the rule base containing rules organized by their function; and (2) the knowledge tables, which are a series of tables listing the order in which the rules appear. **C.** The *knowledge acquisition block* provides the means by which the expert can enter and edit rules or examples of previous decisions. **D.** The *query block* operates a finished expert system, permitting the user to seek advice from the rule base.

Identifying characteristic	Degree of certainty *(percent)*
Floral conditions	
1. Flower is spike	80
2. Florets = 1	75
3. Glumes are shorter	35
4. Disarticulate is above	35
5. Awns are absent	15
Vegetative conditions	
1. Habit is rhizome and stolon	85
2. Blade width is fine to medium	60
3. Ligule is ciliate	50
4. Sheath is compressed	45
5. Collar is narrow	25
6. Auricle is absent	10

Fig. 3. A rule as it appears in the knowledge base. This machine representation of bermudagrass is generated on the basis of vegetative or floral conditions. If either set of conditions is met, the weed can be defined as bermudagrass. The numbers to the right express the degree of certainty with which the identifying characteristic supports the conclusion. The rule is normally not displayed. It may, however, be viewed upon request. *Drawing adapted from O. M. Scotts,* ***Information Manual for Lawns,*** *1979.*

though many areas still require refinement. Research on the development of expert systems for agriculture has just begun. Because AgAssistant was implemented on a relatively small computer with limited memory and resources, the system was developed exclusively for domains that are well defined. A poorly defined domain requires greater computer resources to provide the generalized knowledge necessary for an efficient expert system. At present, it is important that the system be defined very carefully; that sufficient detail be used; and that the size of the problem be limited to one that will be efficient when a microcomputer is used. These limitations restrict the use of AgAssistant in complex tasks. We are therefore turning to other systems.

Currently, the favorite language of artificial intelligence is LISP. LISP-processing machines will allow the development of larger, more complex systems that may operate at even greater speeds. At present these are very costly. If these particular machines prove inadequate, then supercomputers can be recruited for more complex situations.

If the turfgrass identification system, WEED, is to be usable in a practical field situation, the user will need assistance in identifying plant structures during the questioning process. Graphics showing samples of the various plant structures will be necessary to help the user select the appropriate answers. The need for graphics is just one example of how the system is becoming increasingly complex so that, paradoxically, it will eventually become easier for the farmer to use.

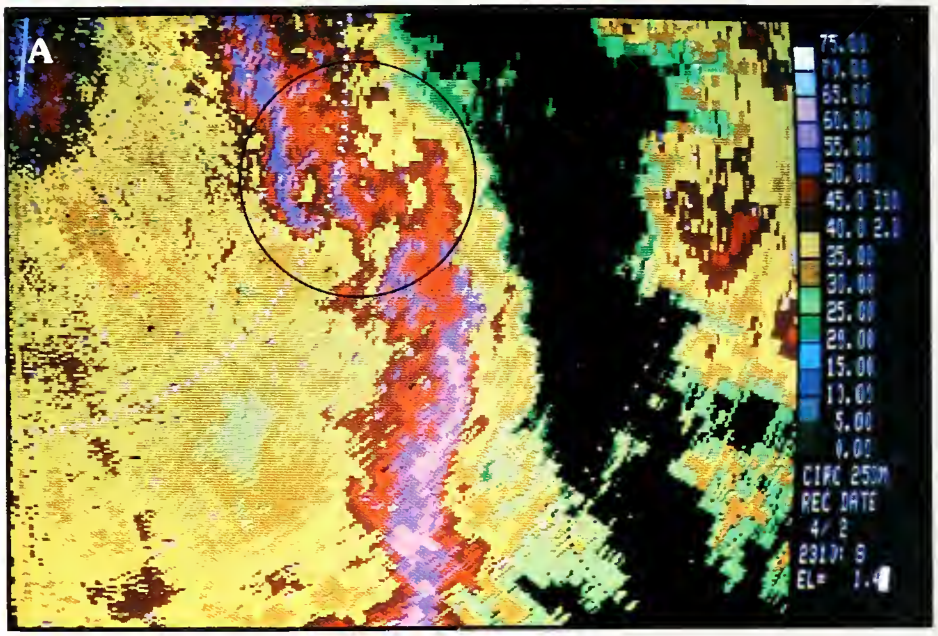
Our final goal is to link individual expert systems to a more comprehensive system so that all aspects of agricultural decision making and control are included. This "system of systems" would then be available for the more general questions or problems that might arise when a farmer is faced with a typical production-related situation.

Thomas W. Fermanian, assistant professor, turf extension □

Code of many colors

Computers play a vital role in weather research. The weather radar collects atmospheric information remotely, and this information is stored and processed by the computer. The computer encodes the information in color images, allowing rapid interpretation of a vast array of data.

Pictures A and B depict a fast-moving line of thunderstorms (squall line) traveling at 40 miles (64 kilometers) per hour across Central Illinois. The unusual occurrence was recorded at 2310:08 hours on April 2, 1982. The Illinois State Water Survey's research radar, CHILL, measured the squall line, using reflectivity and doppler velocity — only two of the several capabilities of the radar. More than one million bits of information are gathered in every sweep of the radar.



The radar is located near the upper left-hand corner of the pictures, and the range markers (curved, white dotted lines) are spaced at 25 and 50 miles (40 km and 80 km) from the center of the radar.

A. *Reflectivity* measures the amount of energy being reflected from a cloud. Television reporters routinely show viewers reflectivity during newscasts. In general, the higher the reflectivity, the greater the rainfall rate and the greater the energy return from within the clouds.

The red and lavender regions depict a squall line. The wave within the black circle occurred at 25 miles (40 km) and indicates an area of lowered reflectivity (and therefore less rainfall). The yellows and light greens represent the clouds that surround the squall line.

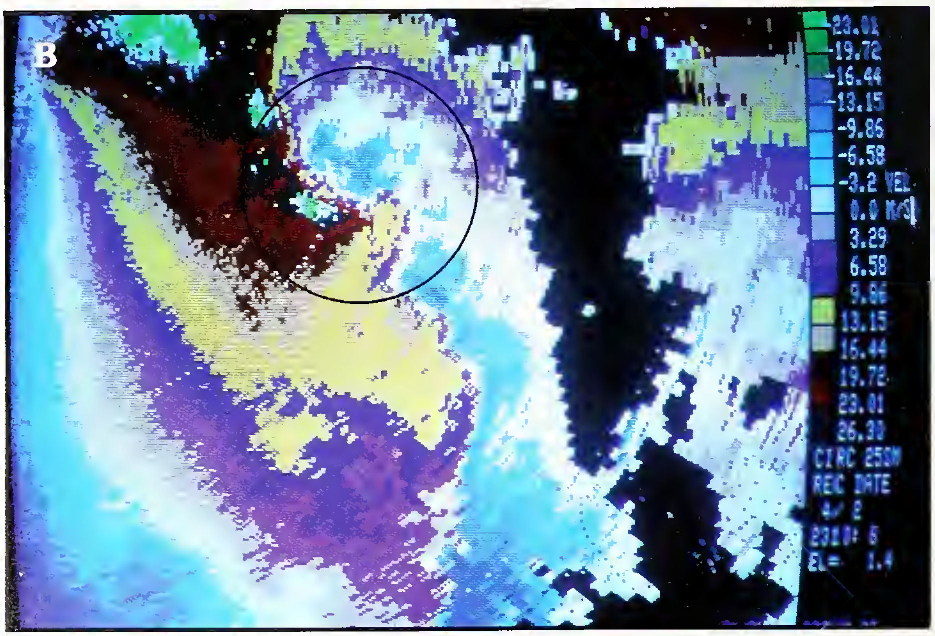
B. *Doppler velocity* measures the speed of the winds as they move to and away from the radar. It provides an insight into the circulation pattern of clouds. Doppler velocity is a relatively new capability, which will be a feature of the next generation of radars that the National Weather Service and others employ.

The blues and greens are raindrops or other material moving toward the radar, and the lavender through red shades are raindrops or particles moving away from the radar. The speeds at which these particles are moving are shown in the scale on the right-hand side of the picture. Generally, the area behind the leading edge of the squall line indicates that the winds are moving away from the radar at a speed greater than 58 miles (93 km) per hour in the red and black regions. In advance of the squall line, the winds are blowing toward the leading edge of the squall line (blue and white regions) at speeds greater than 29 miles (46.5 km) per hour.

In the vicinity of the wave shown within the circle in picture A, a turning of the velocities is evident, which indicates a strong, intense circulation. Such a circulation has been identified with thunderstorms having associated tornadoes. On this occasion, a tornado was indeed present.

It is hoped that increasingly sophisticated radar equipment along with more powerful computers will provide information for improving warnings and forecasts. They will, for example, allow for earlier and better warnings of tornadoes and other phenomena.

Photographs and text courtesy of John L. Vogel, Illinois State Water Survey.



Machine Vision

Marvin R. Paulsen

Machine vision involves the process of taking visual information and converting it into a form that a computer can recognize and use in decision making. Several criteria are employed by the computer for these decisions: the orientation of the viewed object; location of the object relative to some fixed point; and the presence of defects in the object viewed.

Often, machine vision systems are coupled with robots to perform tasks such as repetitive welding; they also locate and orient small parts for robot assembly lines. To increase productivity, more and more manufacturing units are automating their operations with the help of machine vision systems.

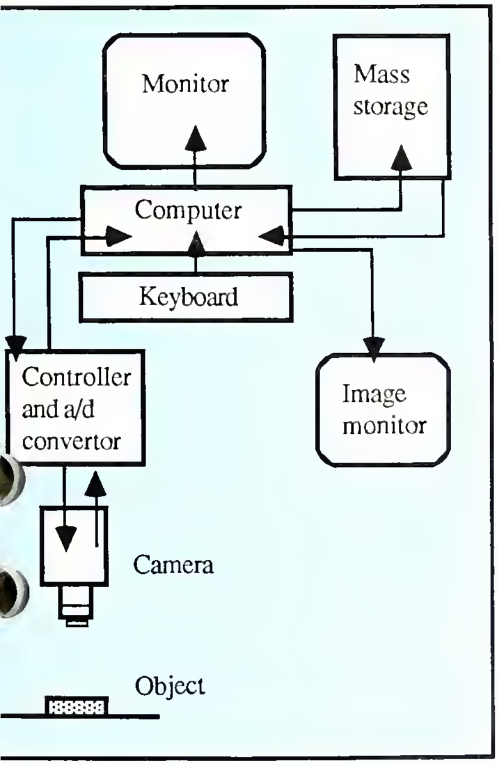


Fig. 1. Components of a typical machine vision system.

A basic machine vision system consists of five components: (1) a *camera*, which views the object and holds electrical charges in proportion to the intensity of light received; (2) a *camera controller and analog-to-digital convertor*, which allows the camera to scan the image of the object line by line and to convert the received signal to digital form; (3) a *computer and software*, which read and store the digitized image, performing whatever image processing is needed to filter noise or enhance the image so that the computer can make decisions; (4) a *monitor*, which allows the operator to view the image that is being processed; and (5) *storage devices*, such as hard disks, floppy disks, and tape drives, to store the images permanently if so desired. (See Fig. 1 for a schematic diagram of these components.)

Peripheral equipment, whose importance should not be underestimated, is also necessary. This equipment includes devices, such as a light chamber, to illuminate the viewed object; lenses and camera filters to allow light of only certain colors or wavelengths to reach the camera; equipment to hold or position objects so that objects will be oriented properly relative to the camera; and finally, conveyors to carry and segregate objects that have been sorted according to prescribed criteria.

A machine vision system operates fast enough to keep up with an object being conveyed underneath a camera so that sorting can occur in real time. Machine vision has been used for sorting cucumbers by length, diameter, and curvature; for separating tomatoes by color and surface scars; for pattern recognition of plants by leaf shapes; and for measuring spray droplet size and distribution patterns.

Currently, a machine vision system is being developed in the Department of Agricultural Engineering here at the University of Illinois to detect defects in corn and soybean quality. The images in Figures 2 and 3 were obtained on a machine vision system that the author used at the Department of Biological and Agricultural Engineering at North Carolina State University. Figure 2 projects the image of a corn kernel as well as its exposed starch. Figure 3 depicts soybean seedcoat crack and purple mottling on a soybean. These details are important in an analysis of grain quality. Clearly, machine vision has a vital role to play, especially in regard to such factors as kernel surface cracks, exposed starch, length-to-width ratios, shape, and discoloration.

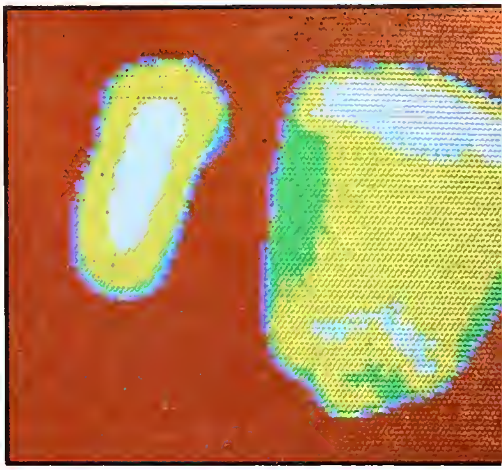


Fig. 2. Image of corn kernel and exposed starch. Left: Note the contrast between regions of exposed, floury endosperm and vitreous endosperm in corn kernels cut transversely. Right: Floury endosperm shows through the crown of a whole kernel.

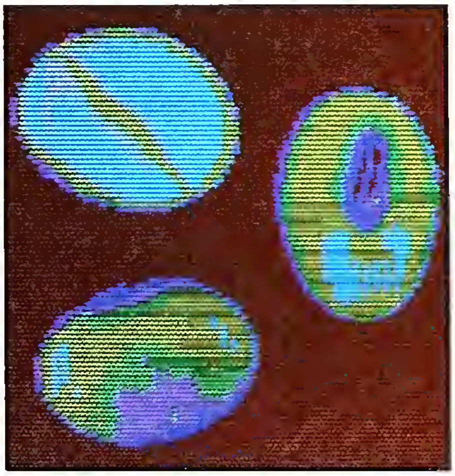


Fig. 3. Digitized images of soybeans, showing a seedcoat crack (top left), a dark-colored hilum (right), and purple mottling (bottom).

Marvin R. Paulsen, associate professor of agricultural engineering □

Electronics in Livestock Production

Sidney L. Spahr and Hoyle B. Puckett

In recent times, livestock producers have seen a rapid change take place in the management of their farms, their animals, and their records. The use of computers for strategic planning is fast becoming a common practice on many farms. Less common but still evident is the employment of computers and electronics as aids for the routine, daily chores of livestock production. Computers are used for the automatic control of equipment; electronic sensors for automatically recording production data; and advanced analysis methods to improve tactical (short-term) livestock management decisions concerning individual animals.

Electronic identification of animals. Commercial systems for electronically identifying livestock represent the major technological breakthrough that is affecting the development of livestock automation (Fig. 1). The first systems appeared in the United States about 1979. Since then, the electronic units worn by the animal have become smaller, more reliable, and cheaper. They have also increased in capacity. Some commercial systems now available have a capacity of 10 billion numbers. These numbers are used to identify individual animals. Because units are mass produced, users have no guarantee that the units they will receive are numbered in sequence. For ease of use, however, some units may be programmed with sequential numbers after they leave the factory.

Electronic identification systems are continuing to develop, and several companies are working toward specific applications in livestock production. Some of the technical features of electronic identification (ID) systems are illustrated in Table 1. Most of the ID units worn by the cow are powered by radio frequency energy that is emitted from a stationary transmitter. These transmitters are typically located at a feed-dispensing stall, in a milking parlor, or at some other location where animals will be confined. When the ID unit worn by the animal becomes powered, it transmits a unique, electronically coded signal that is received by an antenna. The signal is then decoded and matched electronically with the herd name or number of the animal wearing that specific ID tag.

Table 1. *Technical Features of Commercial Electronic Systems for Identifying Animals*

Source of energy

1. Directed radio frequency energy of a specific frequency
2. Long-life batteries

Kind of attachment

1. Tag around neck
2. Ear tags
3. Leg straps
4. Implants

Range of interrogation

1. Typically about 6 inches (approx. 15 cm)
2. Systems range from 2 inches to about 3 feet (approx. 5 cm to 1m)

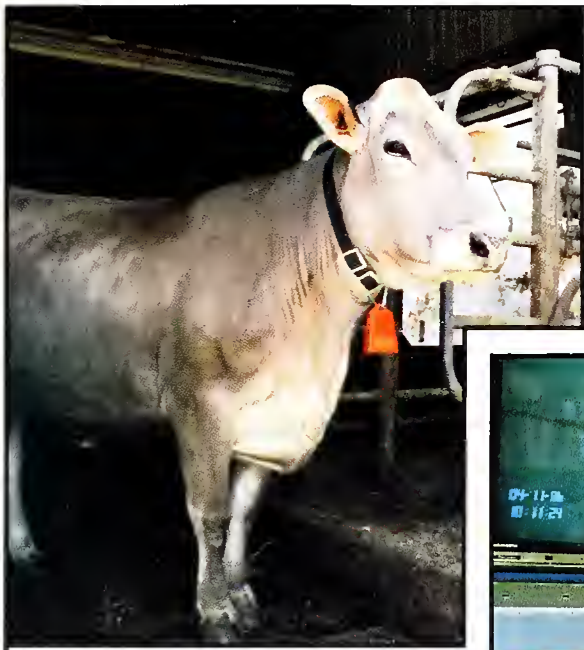
Method of identification

1. Pulsed code at a specific frequency
2. Surface acoustical wave

In our research on these systems, we have found that they can be applied in many ways to enhance livestock production practices. We have also found some systems to have specific features that make them better for some applications than others. For example, implanted devices usually placed beneath the skin can be permanent and can be used to monitor biological changes (such as tissue composition and temperature). However, most of the identification units are too large to be feasible as implants. A typical unit is 3 inches (7.6 cm) in diameter and 3/4 to 1 inch (1.9 to 2.54 cm) thick. Implanting usually reduces the range of interrogation, a factor that is important because implants require that the transmitter-and-receiving antenna be within about 6 inches (15.24 cm) of the ID unit. Because radio energy is absorbed as it travels through the skin to the implanted unit, more power is required to operate a system that is implanted than one that is not. A technical limitation in many of today's systems is that they are not powerful enough to be used as implants.

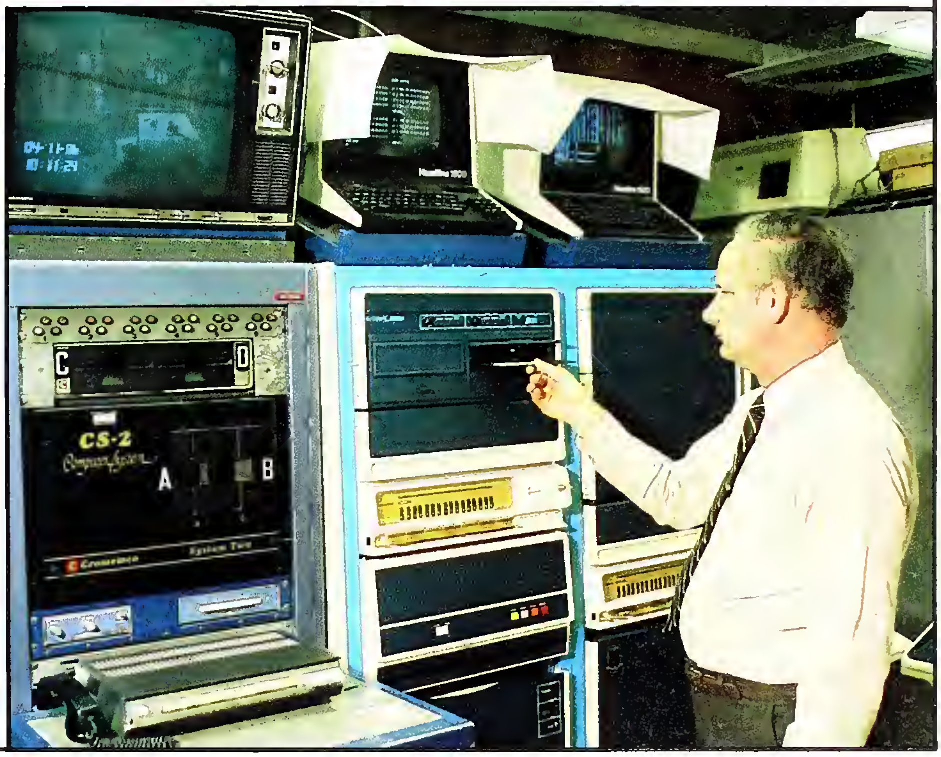
Major improvements in the life of batteries has led some developers to design identification units that are battery-powered. This approach is especially useful if producers wish to attach a physiological sensor to an electronic ID unit. Examples of such units under development for livestock are temperature sensors, activity tags, and tissue-composition sensors.

Automatic feed dispensing. In livestock production, electronic identification is used most widely for computer-controlled feed dispensers. These dispensers give concentrates automatically on an individual basis



Cow with electronic identification tag around her neck.

Co-author Sidney Spahr works with the on-farm computer located at the University of Illinois Dairy Farm.



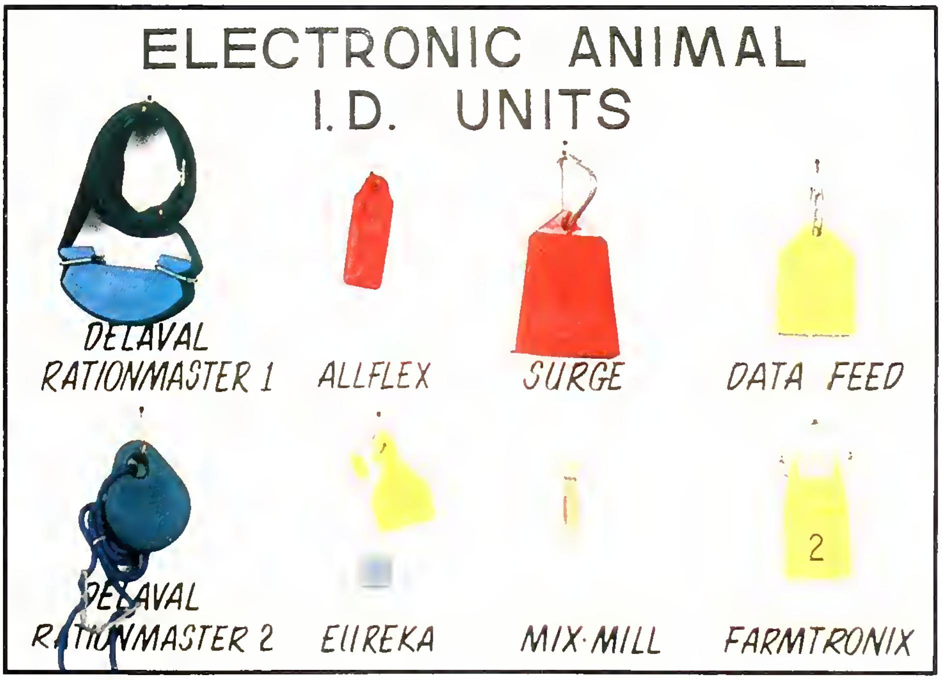


Fig. 1. Examples of commercial animal identification units.

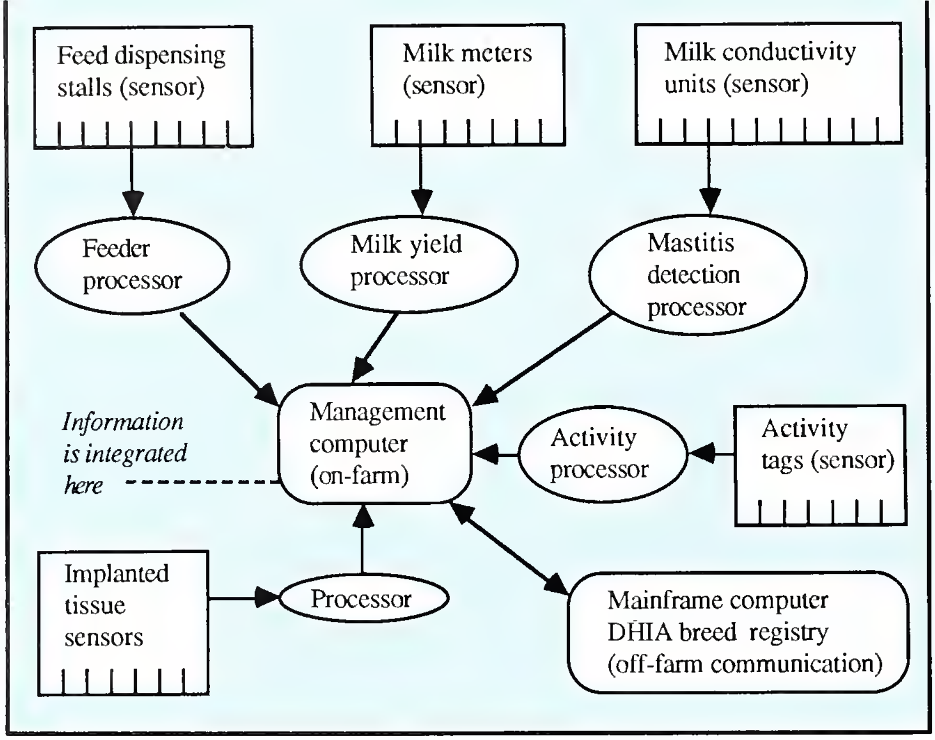


Fig. 2. Advanced data collection and analysis system for dairy farms. A data-collecting device is located at each sensor, and information is controlled by a processor. Each sensor along with its processor can stand alone. The processed information is integrated at the management computer on the farm.

to cattle housed in groups in a feedlot. When dairy cows having widely different daily milk yields are housed in the same lot, it is common for the computer to control not only the amount of concentrates dispensed to each cow but also the protein percentage in those concentrates. The goal is accomplished by using a dual feed dispenser that dispenses two feeds — soybean meal as a protein supplement and corn as an energy supplement. Feed proportions differ, depending on each cow's individual nutrient requirements. The computer controller keeps a record of the amount of feed dispensed to each animal and spreads the amount out over several meals (typically 6) to reduce the indigestion associated with feeding overlarge amounts of concentrates at one time.

One of the new developments in automatic feeding is "closed loop ration balancing," a system pioneered by the University of Illinois. In this system, a ration-balancing program estimates each cow's consumption of a measure (bunk mix) of forage, which is fed free choice. The computer program considers the cow's weight, her daily milk production, the fat content of her milk, and the quality of the forage as indicated by the fiber content. The program also contains built-in minimum recommendations for forage consumption. These recommendations are intended to prevent the percentage of milk fat from being abnormally depressed — a condition that occurs when diets contain too little fiber. The concentrate requirements necessary to balance the estimated intake of bunk-fed forage are then transferred electronically from a personal computer to the feeding computer.

An integrated approach. An outline of the type of system that is evolving for livestock management is depicted in Figure 2. Generally, the system consists of dedicated data-collection devices that run continuously, perform their tasks automatically, and communicate periodically — perhaps daily — with an on-farm management computer containing the herd records. These dedicated data-collection devices will have microprocessor controls that can perform preliminary computations to provide concise summaries of the data collected in real time (as it happens). The summaries will be printed for the manager and transmitted to the management computer.

The management computer will be an advanced version of today's personal computer. It may also be linked to mainframe units by a modem and telephone lines so that the information can be transmitted to a regional dairy records (DHIA) laboratory, a veterinary clinic, a breed organization, an artificial insemination organization, or to commercial agricultural data bases.

Electronic detection of estrus. The application of electronic sensors to detect estrus is currently receiving considerable emphasis at the University of Illinois. Because gestation is about 280 days, it is essential that a cow become pregnant by the 85th day after the birth of the previous calf. This cycle will maintain the 365-day interval that is desirable for maximum economic returns. It costs dairy producers an estimated $2 for every day (after the 85th day) that it takes to get cows rebred. Thus a missed estrus period is costly enough to justify investing considerable resources to maximize estrus detection.

We are developing and testing two electronic sensors designed to be estrus-detection aids. One sensor is an electronic activity tag that the cow wears around her leg. The model we are testing is a self-contained recording unit with lights that flash on when the activity of the cow increases beyond a threshold built into the unit. We manually transfer the activity counts that accumulate at 2-hour intervals to a personal computer that analyzes activity patterns. This approach appears promising, especially as the technology advances to improve the useful life of the units and to allow automatic transfer of the data. For example, the data could be transferred automatically as the cow walks through an archway containing an electronic reader. No physical contact would be necessary. The technology is similar to that currently used by department stores to prevent theft of clothing.

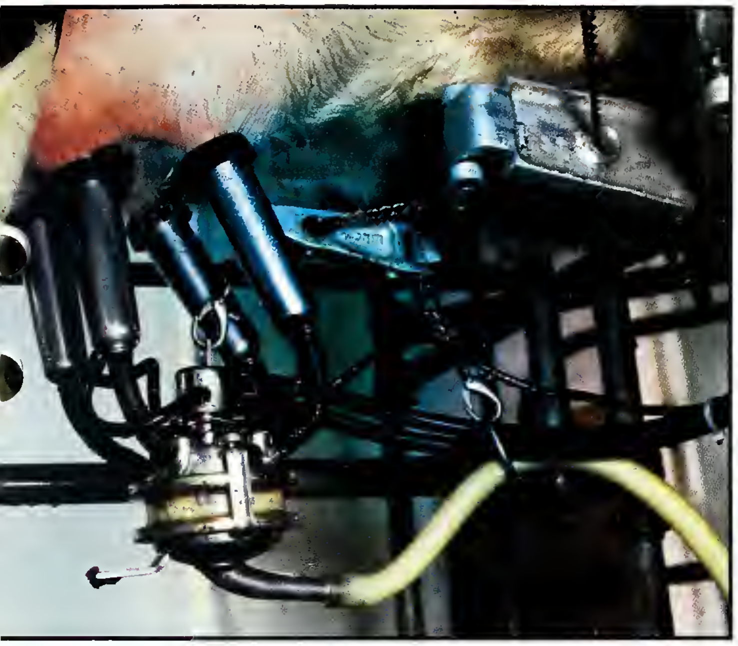


Fig. 3. Close-up of milking claw in use. The claw has four teat cups, a lid assembly equipped with devices to check milk conductivity and temperature, a glass bowl where milk from the four quarters temporarily accumulates, and a bottom from which the milk flows out. The information collected is recorded on a computer and processed.

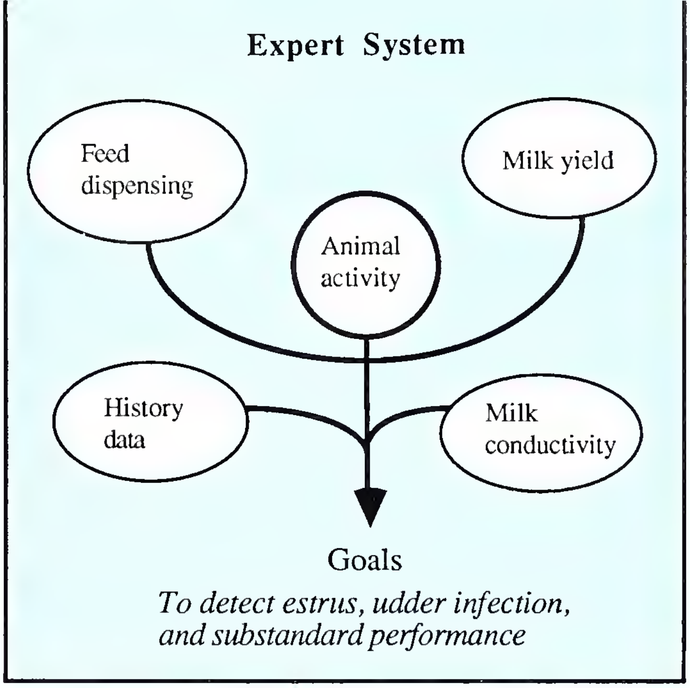


Fig. 4. Expert systems, using a convergent analysis approach, collect livestock information from many sources, analyze data for each animal, and identify animals that are in estrus or otherwise need individual attention. All the information converges and is analyzed by the computer in accordance with a specified goal.

A second electronic sensor being researched by our group is an implanted sensor that estimates the changes in tissue hydration occurring at estrus. The changes are known to occur under the influence of the reproductive hormone, estrogen. Preliminary evidence indicates that such changes can be monitored through accompanying changes either in the electrical conductivity of the vaginal fluids or in the tissue surrounding the reproductive tract. A major effort is currently being made to connect these sensors to an automatic recording system at our dairy research farm. Although this unit is being developed for dairy cows, the long-range implications will be similar for beef cattle, swine, horses, and other livestock.

Electronic detection of mastitis. Scientists have been intrigued for years with the possibility of developing an automatic system to detect subclinical mastitis during the milking process. We have developed the first such system in the United States, complete with automatic recording in real time, data analysis in the milking parlor, and specific algorithms to discriminate between infected and uninfected quarters of the udder. (Each quarter of the udder is anatomically independent and has its own secretory tissue.)

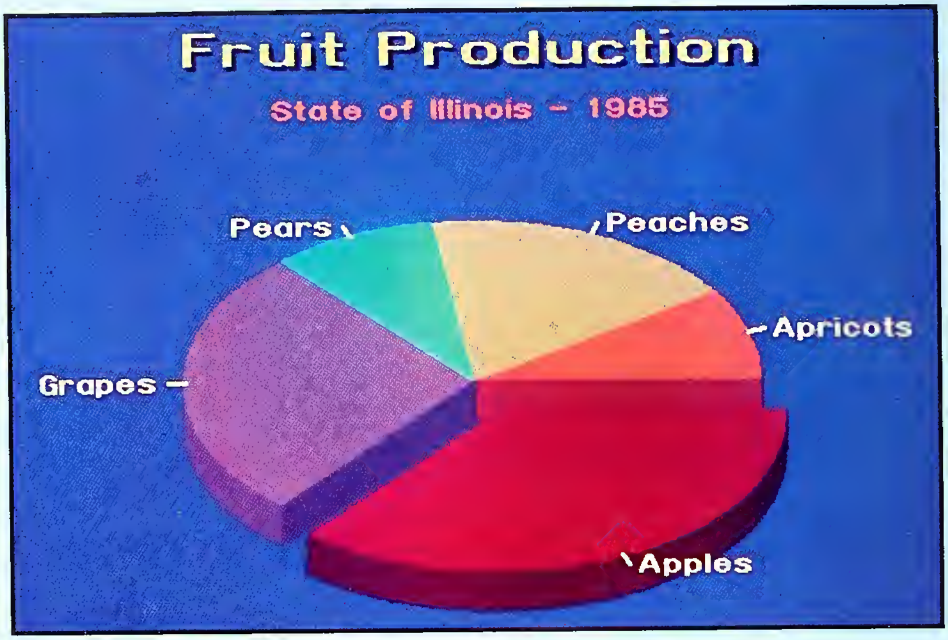
In our system (Fig. 3), we insert conductivity cells and probes into the milking machine claw to measure milk conductivity by quarters before the milk from the different quarters is mixed. Values, transmitted to a microcomputer, are recorded every 6 seconds. Incremental milk production is also monitored at 6-second intervals. During the past year, we have begun to identify cows electronically in the milking parlor to complete the automatic recording scheme.

Advanced data analysis via expert systems. We have just begun to develop a new and advanced system for automatically analyzing data. The detailed data described so far must then be condensed into meaningful information for the herd manager. For this purpose, the "convergent analysis" (Fig.4) approach is used. Data are collected from many sources for each animal. Algorithms are developed to describe expected behavior of each variable from day to day or milking to milking. Analyses, conducted simultaneously on several variables, help locate aberrations from the norm. Although our knowledge of the patterns will be programmed initially, the expert system can ultimately learn by itself to distinguish more finely between normal animals and those that are in estrus, have infections (for example, subclinical mastitis), or are subnormal in their performance.

To date, we have advanced to the point that we know approximately how much variation can be expected under normal conditions for most of the variables. We know approximate patterns and thresholds that indicate when specific management events will occur. Our efforts in the immediate future will focus on the application of expert systems analysis to convert the data into useful information.

Sidney L. Spahr, professor of dairy science, and Hoyle B. Puckett, professor emeritus, Department of Agricultural Engineering □

Graphically speaking



The Photography Section of the Office of Agricultural Communications (OACEE) is producing computer-generated slides for faculty and staff in the College of Agriculture. Materials produced include word frames, simple charts, and bar and line graphs. Photographer Larry Baker says that with the introduction of computerization, turnaround time for producing presentation-graphics has been cut by one-third, and volume has increased 300 percent.

At the moment, the equipment being used consists of an IBM-AT personal computer and a polaroid palette image recorder. The palette can produce 64 different colors and use as many as 16 colors on one slide. Baker says the Photography Section is keeping abreast of developments in software in order to eventually expand the section's electronic capabilities. Since purchasing the system in mid-January, says Baker, the office has produced over 1,200 different slides for the College of Agriculture.

Mapping insect problems

Over the past four years, Extension Entomology has been using computers intensively. Much of the pest information contained in the *Insect, Weed, and Plant Disease Survey Bulletin* (IWPDSB) — the weekly newsletter of Extension Entomology — is analyzed with the help of a computer. According to Charles Guse, Extension entomologist, data may be collected on subjects as varied as black cutworm pheromone trapping or degree-day accumulations for the life stages of alfalfa weevil. Traditionally, this information has been reported in numerical tables. Because of space limitations, most of the data have been summarized into district averages.

"Unfortunately, insects pests don't restrict their habits to the lim-

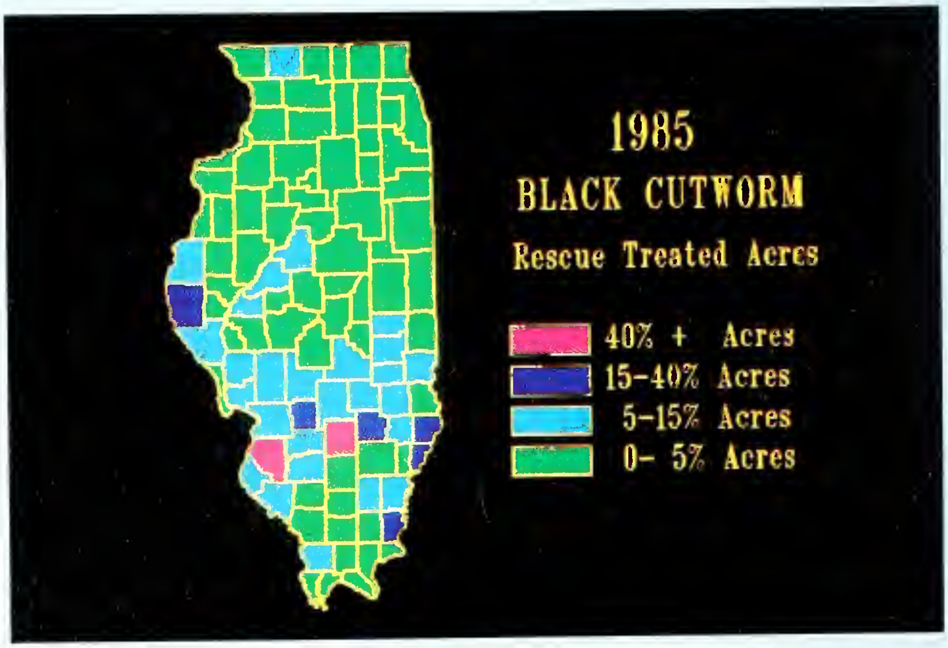


Fig. 1. The percentage of acreage in each county rescue-treated for black cutworm in spring, 1985. The map-photograph was produced on a computer-camera system at the Illinois Natural History Survey with data from county Extension advisers. Similar maps are being produced in black and white for the weekly Extension newsletter. Maps are transmitted with text over telephone lines to county Extension offices throughout the state using the College of Agriculture computerized information delivery system.

its of our political boundaries. Most of the reports of damage, infestation levels, and predictions of pest life cycles are more easily understood when they are shown on a map," says Guse.

Although mapping insect problems has always been a useful method of reporting results, producing these maps has been a painstaking chore, requiring several hours of work for each map. In the past year, Extension entomologists began using computer-generated maps to depict insect problems. Specialists can now produce these maps in a matter of minutes by combining insect data from county Extension advisers with weather data from the Illinois State Water Survey, and by using specialized mapping software on the Geographic Information System computer at the Illinois Natural History Survey.

The speed with which maps are produced allows Extension entomologists to analyze insect problems as they occur throughout the state. Entomologists can compare reports of infestations with various causal factors, such as temperature and precipitation. They can then report their findings faster, says Guse, in a format that is more accurate and understandable than those used before.

In addition to generating maps for research and analysis, the computer can reproduce these maps as photographs (Fig. 1), slides, or black-and-white camera-ready copy for publications. Several options are thus available for disseminating information to the public.

Beginning in 1986, these maps will be included in the IWPDSB as part of the regular method of reporting seasonal problems. In addition, the data for the maps along with a variety of other products will be available to the county Extension advisers as part of a pilot College of Agriculture computerized information delivery system. Computerized mapping and information delivery will result in a significant improvement: information will be received more rapidly, and problems will be analyzed more easily.

Publications

More about Computers

The publications listed here provide additional information pertaining to this issue of *Illinois Research*. Some of these publications are reference tools; others provide general background information; and still others relate specifically to topics addressed in individual articles.

Reference

Agricultural Databases Directory. M. E. Williams and C. G. Robins, editors. 1985. USDA National Agricultural Library, Bibliographies and Literature of Agriculture, number 42. 272 pages.

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Specific

Agricultural Electronics: 1983 and Beyond. American Society of Agricultural Engineers. 1984. Proceedings of the National Conference on Electronics Applications. Two volumes. Vol. 1: ASAE publication 8-84, 342 pages. Vol. 2: ASAE publication 9-84, 456 pages.*

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* Available from The American Society of Agricultural Engineers, 2950 Niles Road, St. Joseph, MI 49085.

The Food Security Act of 1985: Process and Product

Robert G. F. Spitze

The signing of the Food Security Act of 1985 on December 23 was a legislative milestone, marking yet another stage in the evolution of public intervention in the agricultural sector. The efforts of government to influence the prices of farm products and the incomes of farm families began with the Agricultural Marketing Act of 1929. The 1985 Act contains the most comprehensive legislation enacted so far. It followed the most extensive research and education since 1929 and the widest participation by citizens and their representative organizations.

Of all such policies over this 55-year period, the 1985 Act is likely to have the greatest economic impact on farmers, consumers, agribusinesses, traders, and taxpayers. Many decision makers, including the President, strongly proposed a very different approach — the elimination of such policy. The final compromise, however, reaffirmed that governmental policy will continue for at least another five years. The final outcome also belied predictions, often made by economists, that a policy revolution — a watershed in agricultural legislation — was at hand.

Why the policy

The 1985 Act was timed to coincide with the expiration of the 1981 policy. Although some of the problems that precipitated the first price-income policy half a century ago still persist, new problems have continued to appear.

What has persisted is the increasing instability of agricultural production, prices, incomes, and exports. Since the last Act, farm prices have again diverged from prices paid, as have farm from nonfarm incomes. The farmers' rate of increase in product output per hour is fourfold that of all nonfarmers. As a result of this productivity, agricultural adjustments have been continuous, driven inexorably by technology and competition. However, food consumption is still inadequate among lower income groups, and starvation exists amidst a world of surpluses.

Recently, some economic conditions have been found to differ from those of previous years. In 1984, world markets were burdened as total food production rose 4.5 percent. For the next year, crop production in the United States jumped by 6 percent. Farm bankruptcies rose rapidly as the most severe economic crisis since the 1930s overhung the agricultural sector. Note the striking differences between the 2-year periods preceding the 1981 and 1985 Acts (Table 1).

Compared with 1979-80, agricultural exports in 1983-84 dropped 18.5 percent; prices received by farmers were 19.5 percent lower; farm interest costs jumped 12.6 percent; and total farmer net income declined by 26 percent. Treasury costs of farm programs, though a small part of the rapidly rising federal budget, rose from 0.6 percent to 1.6 percent.

What is the policy?

The 1985 Act continues all major existing programs for farmers, low income consumers, and exporters, but also introduces some important changes (Table 2).

Price support levels (nonrecourse loan). Rates for almost all supported

Table 1. *Recent Changes in Variables Affecting U.S. Policy*

Period	Agricultural exports	Farm prices received index*	Total farm interest costs	Total net farm income
	(constant '82$)			
1979-80	$44.2 billion	161.8	$17.8 billion	$31.6 billion
1983-84	36.0 billion	130.2	$20.1 billion	$23.4 billion
Change	−18.5%	−19.5%	+12.6%	−26.0%

* 1977 = 100

Sources: USDA, ERS, U.S. Council of Economic Advisers.

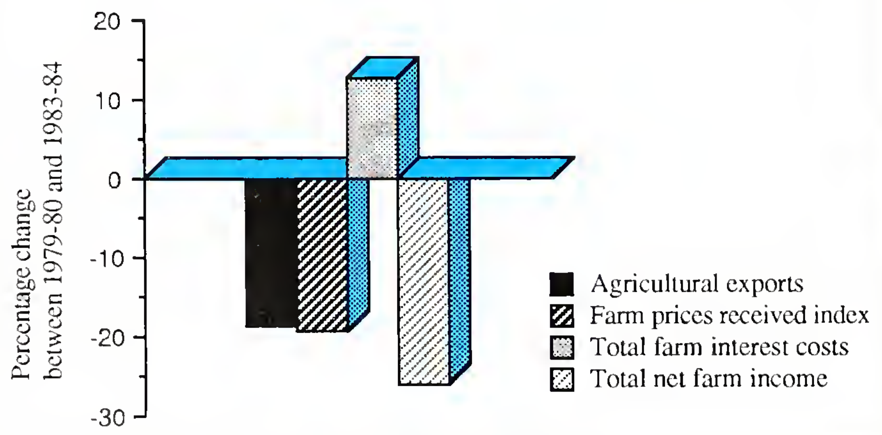

Table 2. *Food Security Act of 1985: Summary of Provisions*

Item	Provisions	Comparison with 1981 Act
Duration	5 years	One year longer, beyond next election
Food aid *Domestic*	Food stamps, emergency aid, and education continued; slightly higher funding	Similar; states must offer employment help
Foreign	P.L. 480 continued; more restrictions	Similar
Grain reserves	Farmer-owned reserve continued; both maximum and minimum quantity levels	Maximum added to avoid use of reserve to support prices
Commodities *Grains*	Voluntary production control; minimum set-aside; discretion for cross-compliance and paid diversion; moving bases	Similar but with more options at discretion of Secretary
	Price supports related to 5-year moving average price; maximum 5% change per year; discretion to lower 20% if prices are low	Initial support lower; more administrative discretion; new moving price base
	Target prices slightly lower each year; advance deficiency and PIK payments	Initial level similar; declines instead of rises
Soybeans	Price supports set similar to grains; no target prices or production controls	Similar
Sugar	Price support $0.18 per lb; strict imports	Similar; no Treasury cost
Dairy	Price supports slightly lowered; production control by whole herd buyout	Support declines instead of rises; new herd buyout
Payment limits	$50,000 per year per producer with some waivers if support lowered as far as possible	Similar
Conservation	Sodbuster program denies program benefits if erodible land is plowed	New
	Conservation reserve of 40 million acres of erodible land by competitive bids for annual rental; shared cover costs	New
Exports	Export enhancement with credits, PIK bonuses, subsidies, and trade promotion; over $5 billion annually in outlays or guarantees	More programs aimed at competitor policies; more direct subsidization; higher funding
Credit	Continued FmHA for farmers; funding shifts from direct to guaranteed loans	More emphasis on farm and less on community services
Research and education	Continued formula, matching, and competitive grants programs	More restrictions; emphasis on technology, new uses
Miscellaneous	Promotion checkoffs; advisory commissions; aquaculture, animal welfare, and related programs	More special programs and mandated studies

products will vary with changing market prices and be permitted to decline gradually from an initial level that is set below previous ones. In contrast, levels in past decades were geared to parity, costs of production, and rigid rates. For example, current legislation sets corn price support at $2.40 per bushel for 1986, with further discretion to the Secretary of Agriculture to lower it to $1.92 per bushel (now $1.84 with the Gramm-Rudman-Hollings amendment). If carryovers remain large, prices will be substantially lowered by 1990.

Target price levels. Although rates initially will change little, they will slowly decline by about 10 percent by 1990. For example, the minimum target price for corn is $3.03 per bushel for 1986; it will drop to $2.75 by 1990.

Production control. Voluntary production control with various benefits as inducements will continue. Minimal set-aside levels have been mandated; acreage and yield bases depend on recent, moving farm averages. For 1986, the set-aside is 20 percent if a farmer is to qualify for benefits.

Dairy program. For the first time, production control has been accepted in a 5-year whole herd buyout effort along with lowered price supports, partial funding assessments on farmers' receipts, and a meat buying disposal program.

Credit. Following a half century of direct Treasury credit assistance to both farmers and rural communities, FmHA (Farmers' Home Administration) will be limited primarily to farmers and will mainly substitute federal guarantees for direct outlays.

Conservation. The Act includes the following new major conservation initiatives: (1) denial of benefits to producers who "sodbust" or "swampbust" fragile land; (2) inducements for producers to voluntarily set aside tilled fragile farmland into a 10-year reserve with a minimum goal of 40 million acres to be achieved by 1990.

Exports. New, aggressive public initiatives to regain lost export markets are planned, including the fol-

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lowing: (1) An increase of $2 billion in exports by PIK (payment in kind) enhancement sales. (2) An interest subsidy of $325 million per year to counter foreign subsidization. (3) Short-term export credit annually of $5 billion, and up to $1 billion, in intermediate-term export credit guarantees. Some of these outlays have already been shifted to current income supports.

Implications

Role of policy. The 1985 Act clearly continues a public commitment to intervention in production, prices, incomes, and trade in the agricultural and food sector for the next five years.

Farm sector. The policy offers no direct promise of a turnaround in the deteriorating agricultural economic conditions. Rather, it provides minimal farm prices and income stability, "safety net" protection, and continued support for public research and education. Major adjustments of agricultural resources will continue, but the costs to those in the agricultural sector will be cushioned.

General economy. Current trends in food prices and the availablility of food to low income groups will continue. Both food aid and farm program Treasury costs will rise above recent levels but will still constitute a lower proportion of the federal budget than they did in the 50s and 60s. Public export initiatives are not likely to diminish tensions and retaliatory rhetoric among major trading competitors.

Research. The recurring cycles of plenty, instability, and scarcity show no signs of abating. If as a nation we are to maintain the edge on national food security and a comparative economic advantage, research must become a priority. If we are to inform the citizenry and its elected policy makers of persistent policy problems, present more innovative alternatives, and predict likely consequences, research must become an urgent public responsibility.

Robert G. F. Spitze, professor of agricultural economics ☐

Graphics in this issue

Pages 6, 18, 19, 21, 24, and 25. The diagrams were generated on the MacPlus by using the Apple software program, MacDraw.

Page 9. The graphic was created on the MacPlus with the aid of "fat bits" in the Apple MacPaint program. Fat bits (enlarged pixels) allow detailed rearrangement of pixels.

Page 14. The illustration was generated on the MacIntosh 512 by using the MacPaint program.

Page 28. The bar graph was generated on the MacPlus, using Cricket Graph by Cricket Software.

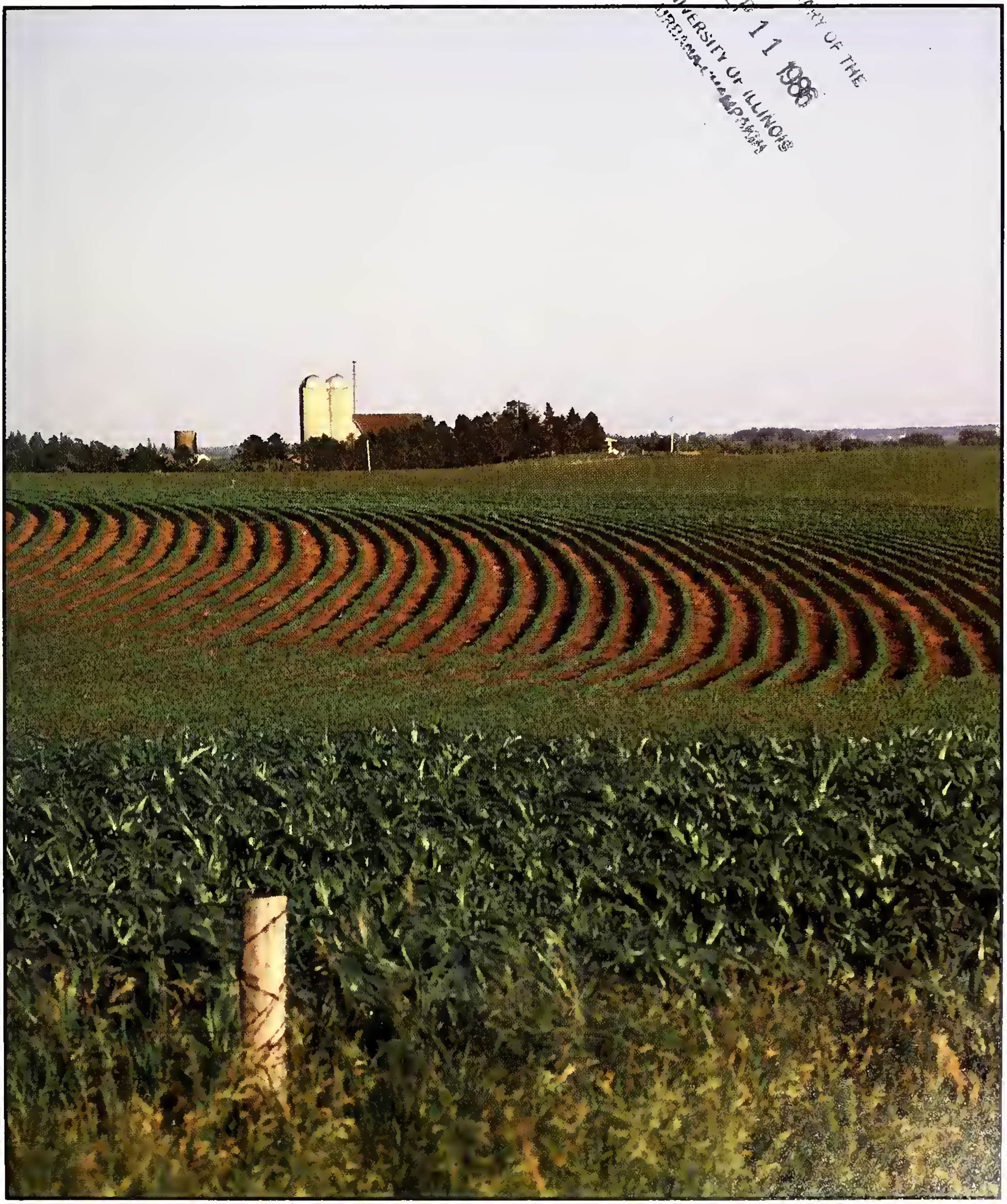
All of the above were printed on the Apple LaserWriter.

Page 13. The three-dimensional graphic was generated on the IBM PC-AT by using Omnigraph software. It was printed on the Hewlett Packard 7470 plotter.

Pages 14. The photograph was created with the MacIntosh 512 and the Apple MacVision program interfacing with a video recorder and a video camera. It was printed on the Apple ImageWriter.

Illinois Research

Agricultural Experiment Station
Fall 1986



College of Agriculture, University of Illinois at Urbana-Champaign, Volume 28, Number 3

The Cover

The richness of Illinois agriculture has been, in large measure, due to its fertile soil and its other natural resources. The people who farm the land have contributed greatly to the development of the state. In depicting a typical farm landscape in Central Illinois, our cover makes a statement about the future of Illinois agriculture. The rich brown earth, the vivid green crops, and the white farmstead on the horizon all convey a sense of well-being. In a difficult time of transition, this landscape reminds us that prosperity in agriculture is not an empty dream.

Photograph from Zehr Photography, Champaign.

"At a time unlike any in the past, we must envision the future."

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Contents

The Future of Illinois Agriculture

Change and Challenge

As Illinois agriculture continues to face difficulties in the mid-1980s, we are troubled by questions about the future: What will we encounter in the 1990s and beyond? Are we heading in the right direction? The future, as we know, is always uncertain, and we can be certain only of one thing — that many changes await Illinois agriculture in the twenty-first century. The way we meet those changes will be a challenge to us.

Certain major forces will powerfully affect the structure of Illinois agriculture and change the face of our rural communities. Developments in research will be one such force: an exciting future awaits both plant and animal agriculture. We can, for instance, look forward to larger litters of pigs because of research on Chinese swine. The use of breeding stock from China, combined with genetic engineering, will keep Illinois ahead in swine production. Illinois farmers will put old products to new use — alcohol as fuel for tractors, cars, and trucks. New products, such as leaner meat, will be developed to satisfy new demands. Marketing strategies will also play a major role. Private and public agencies will continue to market the bounty of Illinois agriculture. Domestic and foreign markets will be aggressively developed.

The future of the College of Agriculture here at the University of Illinois is closely linked to that of Illinois agriculture. The College, too, will face challenge in all of its programs — in resident instruction, research, and extension.

Resident instruction must prepare students in the agricultural sciences to work and live in the twenty-first century. Even at the undergraduate level, students will require skills in the rapidly growing areas of biotechnology and computers. Students will be trained to function in a high-tech environment. They will require strong skills to express themselves effectively in written and spoken language.

The shift to an interrelated world economy will require an understanding of other countries — their political systems, economies, and cultures. Students' horizons will be wider; but they will still require in-depth knowledge of the agricultural sciences.

The scientists involved in agricultural research will use methods, equipment, and ideas that are emerging and still to emerge. Researchers will be at the cutting edge to an even greater degree than they are at present.

The extension professionals of the future will be expected to interpret more complex research than those of the mid-80s. Although group teaching and teaching through the printed medium will continue, we will see a dramatic increase in electronic communications. Extension staff members will be competent agricultural scientists as well as excellent communicators. They will incorporate the new medium into their teaching methods, for they will have to deliver educational programs to a more sophisticated and more highly educated clientele.

Despite the temporary setbacks of today, the future is promising. As never before, farmers, teachers, researchers, and extension workers will all work together to meet the challenge of Illinois agriculture.

William R. Oschwald, director, Cooperative Extension Service □

Illinois Agriculture: Leading the Way

Wesley D. Seitz

Agriculture in times past.
Woodcut entitled "Schnittermahl, Herbstsaat, und Flachshecheln" ["Reapers' repast, Fall Sowing, and Carding of Flax"] by Petrus de Crescentiis, Frankfurt, 1538. Reprinted from Friedrich Zoepfl, *Deutsche Kulturgeschichte*, vol. 2, *Vom 16. Jahrhundert bis Gegenwart* (Freiburg im Breisgau: Herder & Co., 1930).

The senior citizens of agriculture can probably remember when the family farm was almost an island unto itself — with horses for power, wood for fuel, manure for fertilizer, and canning and a smokehouse for food preservation. Seed was saved from the previous harvest, and knowledge derived from the previous generation. Little was purchased or sold, use of credit was rare, and public support and intervention were at an absolute minimum. The quality of the resource base, the skill of the family unit, and Mother Nature determined whether the unit prospered. But even at its best, farming was hard work, and life on the isolated farm was austere.

Looking back, we can see that revolution upon revolution has occurred. Slowly at first, but at an ever-increasing scope and pace, change has transformed American agriculture in ways that could hardly have been dreamed of 75 years ago.

Looking ahead, I find that my crystal ball is cloudy — I am not able to predict the what, when, and where of change. However, by considering the forces shaping agriculture today, we may be able to gauge the challenges that lie ahead.

Adapting to change. The forces that affect agriculture are changing rapidly. And the nature of the changes suggests that this pace will only accelerate. Both the Illinois farmer and Illinois agriculture must be ready to deal with the transformations to come.

The most obvious arena of change is the farm itself. Inventive farmers, private firms, and experiment stations, among others, have contributed numerous innovations. Starting

with simple trial and error and progressing to controlled experimentation, computer-aided analysis, and sophisticated biotechnological techniques, the process of discovery has been dramatically altered. In fact, the creative process itself has undergone revolutionary development.

At the same time, the number and types of organizations doing research have increased. Private firms, universities, and national laboratories in many countries, as well as multinational research consortia such as the International Rice Research Institute, are all joining the race to develop and use research tools. Articles in this issue refer to some of the developments that will result.

It seems safe to predict that the Illinois farmer will face an ever-increasing number of innovations that may or may not be profitably adopted. Farmers will need to choose those innovations that are beneficial for their individual firms. Because we who are committed to agriculture cannot stop the innovative process, we must make a choice. We must either follow others or choose to be among the leaders.

We have chosen to lead in the past. The state's investment in the Food for Century III program is an example of Illinois's commitment to a leadership role. This long-range program, which came into being in 1976, has made possible research and development programs in the Colleges of Agriculture and Veterinary Medicine. The investment of nearly $60 million will provide outstanding research facilities for agricultural scientists. The benefits extend far beyond the College of Agriculture — to Illinois agriculture and to consumers around the world.

Price changes and market development. The early isolation of farm units gave real meaning to the term "feast or famine," as a farm unit's well-being was determined by the weather, pests, and local conditions. In ancient economies, trade was often limited to little more than spices, textiles, and precious metals. Price information was imperfect and moved quite slowly. In the fifteenth century, for example, price changes could take as long as twenty years to be transmitted around the world.

Market developments took place gradually. As markets expanded to link producers and consumers in far-flung areas, to make products available over time, and to transform the output of agriculture into an ever-wider array of products, the farmer was more effectively integrated into a broader economy. The development of markets has allowed farmers to specialize in producing goods they are best qualified to produce.

In large measure, specialization has brought prosperity to producers and consumers. It has also controlled extreme fluctuations in price. As new products and production techniques develop, we can expect further gains from specialization and further changes in the market system.

In recent times, strides in electronic and communications technology have transformed the way markets operate. For example, satellite communication allows prices to be transmitted instantly among all market participants. Yet this technology has not been adopted everywhere.

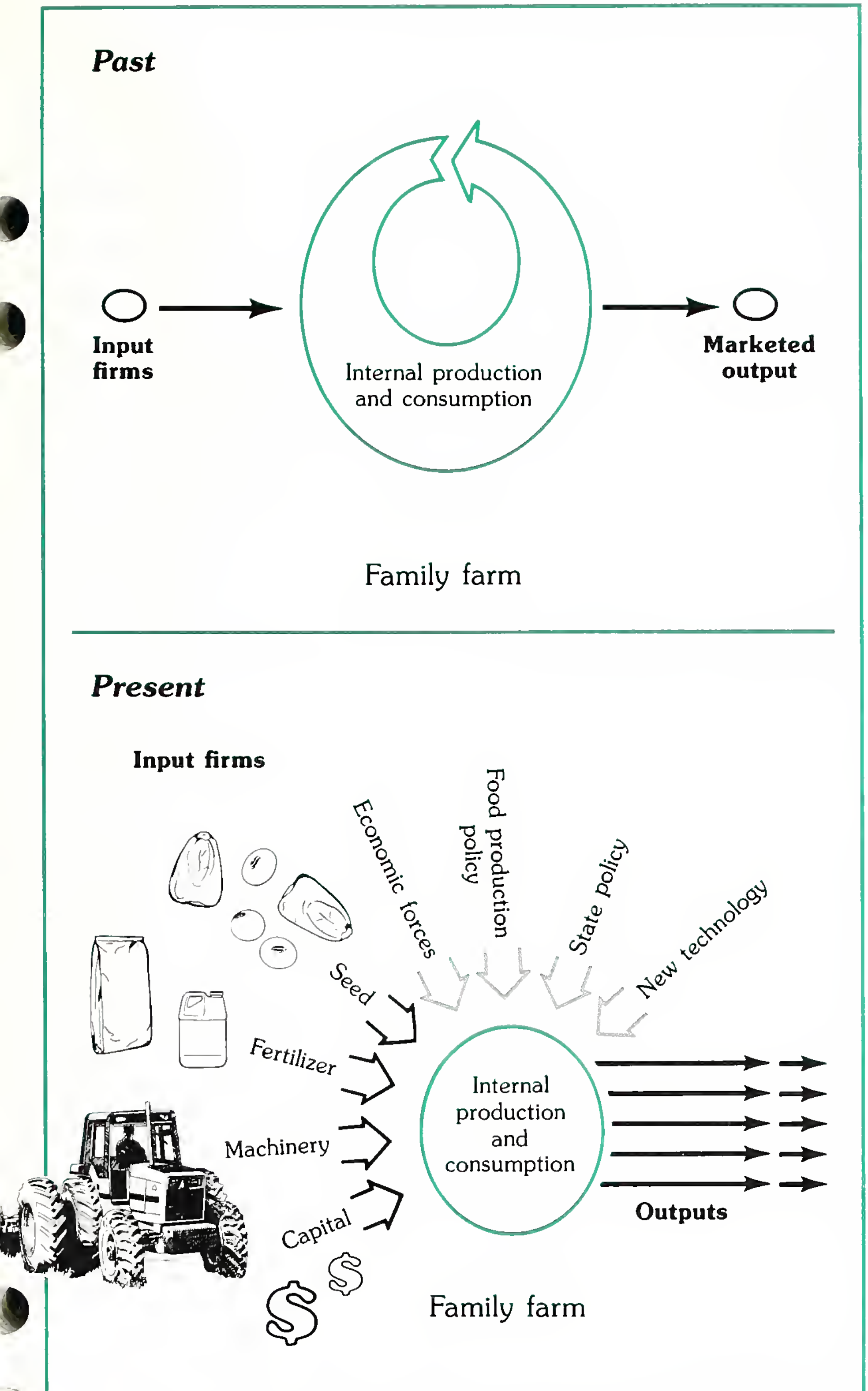
The continued development of new market instruments (options trading is a recent example) will further change the environment in which the farm and agribusiness firms operate. In part due to the work of the Cooperative Extension Service in the state, Illinois farmers are among the leaders in using these market instruments. Many more producers might enhance their profits (or at least reduce their risks) through intelligent use of market instruments.

Input and output firms. Markets link farmers to agribusiness firms, which provide inputs to farm units and process the farm's outputs. These firms have also experienced a rapid transformation. Their products have changed, their business structures have grown more complex, and their territory may have expanded.

Input firms — those producing seed, feed, fertilizer, and chemicals, for example — have received considerable attention from publicly supported institutions, perhaps in part because they are instrumental in bringing new products to the farm.

Output firms, on the other hand, have only recently begun to receive comparable attention. There is a growing emphasis on processing firms, such as food manufacturing or soybean processing firms. This emphasis reflects the increasing recognition that these firms are vital to the competitiveness of the whole sector. The article in this issue by Arthur Siedler and Roscoe Pershing examines the prospects of developing this phase of the agribusiness industry. Resulting developments, especially if targeted to Illinois-produced goods, can enhance the demand for the products of Illinois agriculture.

Clearly, technological developments imply significant change within input and output firms. And this



The forces affecting agriculture are rapidly changing the family farm. **Past:** the family farm was largely a self-contained entity, and production was directed chiefly at consumption on the farm itself. Outside influences were minimal. **Present:** the family farm feels the impact of a multitude of outside forces: input firms (providing seeds, machinery, fertilizer, and capital), as well as economic factors, state and federal policy, and the new technology. In addition, the family farm is now closely linked to an ever-widening sector of output firms.

change will in turn provide the opportunity for other changes that will be implemented by Illinois farmers. Farmers could, for example, grow highly specialized crops for a processing firm with particular needs. Here again, we may choose to be among the leaders or among the followers. But we cannot choose to halt the change or even to slow its pace.

The larger arena. Changes will not only come to Illinois farms from the physical and market aspects of their operations. Illinois farms and all of Illinois agriculture are inextricably linked to the general economy of this country, which is in turn linked to the world economy. Decisions made in the global theatre will largely determine what is produced and processed in Illinois. For example, Illinois agriculture has been profoundly affected by the fluctuation in interest rates and the value of the dollar in world markets during the late 1970s and 1980s.

The GATT (General Agreement on Trade and Tariffs) negotiations also illustrate the point that decisions taken in an international setting can substantially affect the Illinois farmer. For example, the decision made on corn gluten trade will have sizeable repercussions in Illinois agriculture. In some cases, decisions that would have a short-term, positive effect on the agricultural economy could create larger, negative results in the long run. For example, if the United States were to ban the import of meat, the country affected might retaliate by banning grain imports.

The activities of international financial institutions such as the World Bank provide another case in point. International agencies may lend

money to a developing country to enhance the country's agricultural production. This lending activity may appear to harm Illinois agriculture. Over time, however, the activity may create a significant market for a range of higher-valued agricultural products from Illinois, as well as for other U.S. products. Farmers and agribusinesses will need to understand the larger economic scene to determine the implications for their operations.

Public policy. The performance of Illinois agriculture and the well-being of the Illinois farm family is also greatly influenced by public policy decisions at the state, national, multinational, and world levels. The 50-year history of our evolving national agricultural policy clearly indicates the significant impact that that national policy can have on agricultural prosperity. Although state policies may not be as dramatic, they also play an important role.

Taxation policies — federal, state, and local — can affect the individual agricultural firm and the entire sector. The Illinois Farm Development Authority, created in 1981, is an example of a state policy decision directly affecting farmers by providing lower-cost credit.

The federal government's policies on tax rates, investment tax credits, depreciation schedules, and capital gains influence decisions in the agricultural sector. In addition, rulings on the classification of various farm assets, sources of income, and types of expenses also have an effect. According to USDA economist Nelson I. Bills, the tax code at present is set up so that a farm investor contemplating a farmland improvement must consider a bewildering array of 31 tax avenues! The likelihood of tax reform suggests that major changes can occur in this arena. These changes may, in turn, dramatically affect farmers' financial planning.

We find that to an extent state level policy mirrors federal policy. The state balances the income, property, and sales taxes and also determines inheritance taxes. Since tax considerations loom large in the individual farmer's decision making, they can affect the performance of the state agricultural sector.

State and national policies dealing with environmental, health and safety, labor, and other concerns also play a part in the well-being of the farm family. They affect the management decisions made on the family farm.

Decisions in other economies to subsidize their agricultural sectors, decisions taken or not taken by multinational groups (OPEC), and the possibility of international conflict, all have the potential to shape the environment in which agriculture operates. Recent history suggests that the number of interest groups pressuring state and national governments for policies affecting agribusiness will continue to grow. It is reasonable to expect, therefore, that such factors will periodically change the environment of the farm firm.

Steven Sonka's article on the adoption of technology demonstrates the competitive advantage to be gained from adopting technology early. The farmer, state, or nation that responds to a change in the economic, institutional, or political environment in a timely fashion is likely to benefit from the adoption of technology. If we do live in an increasingly complex and changing environment, the payoff from being among the leaders may be tremendous.

Our continued leadership will benefit both farmers and agriculture in Illinois. However, our decision-making skills — our management information systems — must be continually updated to meet the forces of change. Our research base, our ability to translate basic research to a form useful to the farmer or the agribusiness, and the ability of operators to make the correct decision on a timely basis are all crucial if we are to lead the way in the competitive world of agriculture.

Wesley D. Seitz, professor and head, Department of Agricultural Economics □

Illinois's Agricultural Assets

Larry A. Werries

The state of Illinois is uniquely blessed with rich human and natural resources that make our agriculture among the most productive in the world. Enterprising farmers have worked the land since the 19th century. Deep glaciated soils, an extensive transportation system, and a climate conducive to grain cultivation have all contributed to the state's agricultural wealth.

Illinois dominates the heartland of American agriculture. It has been a leader in producing corn, soybeans, and livestock; in processing; and in exporting its products. Due to the proximity of the Great Lakes, the Mississippi, Ohio, and Illinois rivers, and a well-developed rail and highway system, Illinois agriculture enjoys comparative advantages in being able to transport agricultural commodities to other states and nations.

Several world leaders of agricultural policy, agribusiness, and research have been born and raised in Illinois. Jack Block, D. E. Alexander, George McKibben, and the entire Funk family are among those who share the responsibility for our past agricultural achievements and future industrial successes.

Illinois agribusinesses are pioneers and innovators in utilizing and converting raw commodities into value-added food and industrial products. Agribusiness giants such as Deere, Staley, International Harvester, Archer Daniels Midland, Caterpillar, DeKalb, Dickey-john, and others have strong ties to Illinois's agricultural history. These companies have fostered many developments, which range from the steel plow and corn combine to sophisticated monitoring devices and exciting new uses for corn and soybeans. The developments have benefited not just Illinois agriculture, but also farmers all over the world.

Agricultural research enjoys considerable support in Illinois. The state has demonstrated its commitment to new agricultural technology with the "Food for Century III" program at the University of Illinois and other agricultural institutions. This program, in which over $60 million have been invested, will provide enormous research facilities for the Colleges of Agriculture and Veterinary Medicine.

The University has also attracted a future USDA biogenetic research laboratory to the Urbana-Champaign campus. Research conducted in this laboratory is expected to contribute significantly to the rapidly expanding field of biotechnology. In addition, agricultural research will benefit from the National Center for Supercomputing Applications, also located on the Urbana-Champaign campus.

Federally sponsored research is conducted at the Northern Regional Research Center in Peoria, resulting in significant discoveries connected with the utilization of animal feed. Research has also led to the industrial applications of Illinois crop byproducts.

Several state programs designed to protect Illinois's assets will pay dividends to the state's agricultural future. The state soil conservation plan, "T by 2000," is a unique, combined effort by federal, state, and local governments to protect our soil and water resources. The Illinois Grain Insurance Corporation is a model program designed to protect grain producers from financial losses that result from elevator bankruptcies.

Our industry is currently weathering difficult economic times, but encouraging signs of recovery are evident. Lower interest rates and a weaker U.S. dollar will help agriculture regain its financial health. Illinois's rich assets will provide our farmers with a solid, sustained growth, directed towards a brighter future.

Larry A. Werries, director, Illinois State Department of Agriculture ☐

Competition, Technology, and Illinois Agriculture

Steven T. Sonka

Over the last two decades, one of the profound changes affecting Illinois farmers has been the internationalization of the agricultural economy. Illinois's exports of agricultural commodities have grown significantly during that period. Illinois corn and soybean farmers now produce more than 30 percent of their crops for overseas consumers.

Although the growth of export markets has been widely recognized, less attention has been given to recognizing international competition. This competition, however, cannot be ignored. For example, feed grain exports to countries in the European Economic Community (EEC) have declined in relative importance over the last 10 years. A major cause for this decline has been the emergence of EEC producers themselves as effective competitors.

A recent Cornell University study suggests that production costs for major grains are roughly equivalent between the midwestern United States and major EEC producing areas. In considering future options for the structure of Illinois agriculture, we must not only recognize the existence of current and future competitors but also appreciate the role of technological development in an increasingly competitive world economy.

Technology is widely regarded as a major factor affecting agriculture throughout the world. Technology's effects are controversial and complex. When evaluating such effects, we often focus on the social and human adjustments that must be made. At other times we emphasize consumer benefits and gains to those in the vanguard of change. Also important are innovations that reduce the drudgery and danger of traditional farm activities.

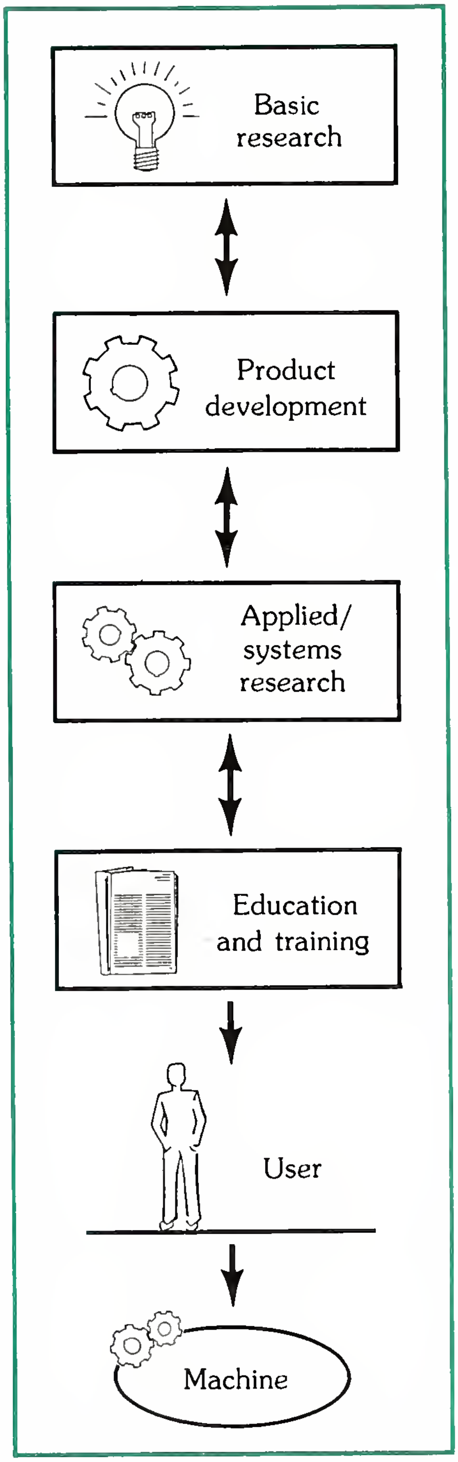


Fig. 1. The process of converting new knowledge into a useful innovation involves several interrelated steps. Basic research provides new knowledge, which leads to the creation of a product (say, a gear). Applied/systems research works to define how existing systems must be altered to accommodate the innovation. Then eventual users must be educated and trained to adopt the product containing the innovation. Feedback and interaction are necessary among all these steps.

The role of technological change in a competitive, international environment, however, differs from its role in earlier times. The remainder of this article attempts to briefly illustrate this role, using examples from the Illinois corn production industry. Although the analysis is simplified, several essential points are discussed.

Steps in adopting technology. Although the discovery of new technologies remains in part esoteric, society does know a great deal about the processes needed to implement those technologies. To understand the processes of change, it is crucial to recognize that discovery itself is only the first step in the process.

Especially from the viewpoint of international competition, the race is not just to be the first to discover new knowledge. Rather, the economic race must focus on who can be the first to refine, evaluate, and effectively implement new discoveries.

Basic research. The process of converting new knowledge into useful innovations involves several steps. Figure 1 depicts these steps and their linkages. Basic research aims at the discovery of new knowledge. Although these discoveries may eventually lead to products with useful applications, such research focuses on breakthroughs that help us comprehend underlying processes.

Developmental research. The results of basic research are generally not directly applicable to society's problems. Instead, basic research often creates fragmented new knowledge, typically produced in a form useful only to other researchers. The process of converting this research into useful innovations involves a number of additional steps (Fig.1). One of these is developmental research, where basic research discoveries are incorporated into new or existing products that are to be used by industry, consumers, or both. For example, considerable research is needed to translate our improved understanding of photosynthesis into effective herbicide products.

Applied/systems research. Simply developing a new product is not sufficient, however. The potential users of the product must fit this new product into existing production or consumption systems. At this point applied/systems research is often required. The goal of this research is to define how existing systems must be altered to optimally incorporate the proposed innovation. In dairy production, for example, it appears that feeding and milking systems will have to be altered to fully utilize biotechnology.

Education and training. After applied/systems research is completed, it will still be necessary to educate and train eventual users. Only after all these steps have been accomplished will the innovation be successfully adopted.

The stages just described do not constitute a static, one-way process. Feedback and interaction between the several levels are necessary to successfully implement technological advances. For instance, the difficulties farmers have experienced in implementing microcomputers illustrates the need for applied/systems research and for user education and training. Furthermore, applied/systems research may prove that a promising innovation is inappropriate for existing production systems. The resulting feedback then can shape future efforts in basic research or product development. It is not likely that such information can be effectively channeled directly from users to basic researchers.

The role of the public sector. The public sector has a vitally important role in the interaction between research and implementation. In nonfarm industries, the basic research function is heavily supported by the public sector. Steps beyond basic research, however, tend to be undertaken by the private sector. Either the firm producing the improved product or firms and consumers utilizing the product conduct applied research.

The structure of this country's farming industry requires a different approach toward implementing research. Often, product development occurs within the private sector because input supply firms are financially able to fund related research. The commercial farm, however, is typically not able individually to fund applied/systems research or to rapidly accomplish the training function. The individual commercial farm is relatively small, and its research capacities are consequently limited.

Technology in a competitive world. The process just described often has been used to justify the expenditure of public dollars for agricultural research and extension education. A major argument in favor of the expenditure has been that it lowers consumer food costs. Although these arguments are valid, we need to expand them to include economic development as a rationale for research and extension activities. To illustrate this point, let us use a simplistic economic model: the purpose of the model is to demonstrate the relative impacts of a cost-reducing technological improvement for corn production. This analysis illustrates the regional effects of differing rates of adoption.

The framework utilized here is a competitive, market-clearing economic model that attempts to estimate benefits to both consumers and producers. A distinctive feature of this discussion is that it identifies benefits to producers in three geographical categories: (1) those in Illinois; (2) those in the rest of the United States (RUS); and (3) those in the rest of the world (ROW). The data used to develop the quantitative estimates represent average conditions for the years 1982-83. The estimates generated here are of a partial, short-run nature. Not considered are the effects on the broader agricultural community, adjustments to asset values, and the total long-run gains to consumers.

To illustrate the effects that the time of adoption has on producer well-being, our analysis sets up a specific, hypothetical situation. In this situation, it is assumed that producers have access to an innovation that will decrease production costs by 10 percent. Instead of assuming that producers in all regions will have access to the innovation instantaneously, however, the analysis specifies that producers in particular areas will be the first to implement the innovation. This allows us to evaluate the benefits and costs of having or not having effective institutions to perform applied/systems research and user training.

The data contained in Table 1 contrast the effects of technological change under two scenarios. In the first, producers in the RUS and ROW categories have access to and have been gradually adopting a technology over a period of 10 years, preceding the time at which Illinois producers began to adopt the technology. This hypothesis presents a situation in which the mechanisms that perform the applied/systems research and training functions are not effectively functioning in Illinois. In the second scenario, Illinois producers have access to the cost-reducing option 10 years before producers in the RUS and ROW categories. In this case, the applied/systems research and training functions are linked to efforts in basic research and product development research.

The absolute numbers in each scenario in Table 1 vary considerably because the size of the geographic areas differs substantially. The relative effect on Illinois producers of these differing rates of adoption is summarized in Figure 2. In the first scenario, Illinois producers are disadvantaged because their competitors have adopted the innovation before they have. In the second scenario, Illinois producers have benefited significantly because they adopted the innovation early. These data illustrate that the economic well-being of the Illinois corn-producing industry (as well as the rural and nonfarm sectors serving that industry) can be significantly affected by technological change — whether that change is implemented within Illinois or not.

A force for change. Increasingly, the role of research and development is being recognized as a force for economic development. Within agriculture, significant technological opportunities appear imminent. The preceding discussion has

Table 1. *Gains from Early Adoption of a Hypothetical Cost-Reducing Technology Applied to Corn Production*

Economic gains to:	Innovation available for 10 years: in RUS and ROW only*	Innovation available for 10 years: in Illinois only
	Millions of dollars	
Illinois producers	−119.8	931.0
RUS producers*	3,728.0	−51.9
ROW producers*	4,899.3	−68.1
Consumers	1,240.6	116.6

Values are in million of 1977 dollars. Estimates over the 10-year horizon are discounted to present value terms.

* RUS = Rest of the United States. ROW = Rest of the world.

The empirical results presented above are from current research undertaken by the following faculty members in the Department of Agricultural Economics: Philip Garcia, Susan Offutt, and Steven Sonka.

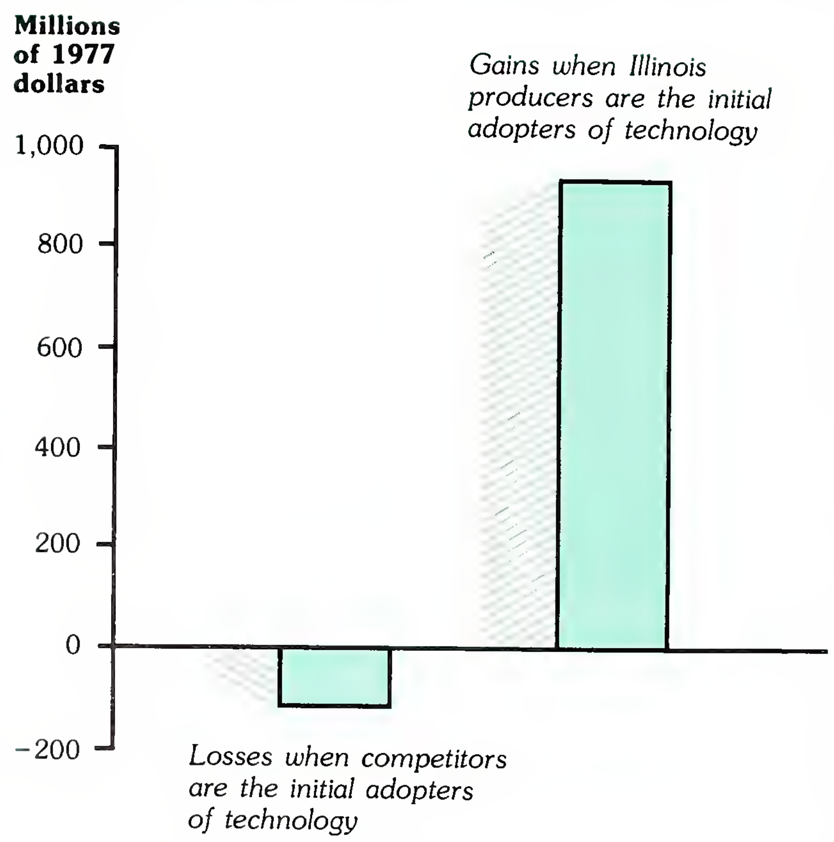


Fig. 2. Economic effects on Illinois producers when they adopt a technological improvement at differing rates. This hypothetical example indicates that Illinois producers will be affected by technological change whether that change is implemented in Illinois or not. Producers benefit by adopting the technology early.

illustrated, however, that basic research is only part of the story. Before technology can contribute to economic growth, a series of interrelated steps have to be successfully completed. Generally, these steps cannot be bypassed, and failure to accomplish them can delay the adoption process.

Innovations often need to be tailored and evaluated in relation to specific geographical locations. The actual adoption of innovations is a dynamic process, and geographic location is only one factor that influences whether a producer uses a new product. In agriculture, however, innovations often have geographically related parameters, such as soil type or climatic conditions. The College's research farms, located throughout the state, are vital mechanisms in this context. They evaluate and tailor innovations to specific geographic needs.

The empirical example analyzed earlier in this article illustrates that research and development institutions that make innovations available early are vitally important to Illinois producers. The simplistic nature of this example should not lead us to underestimate the social and human costs associated with adjustment to technological change. Indeed, significant research and education efforts emphasizing that adjustment process will be critically needed in a competitive environment.

The analysis illustrates that adjustment costs in both human and monetary terms will be most severe in regions that do not have the capability to implement emerging technologies. Although numerous other factors will eventually interact to determine the future structure of Illinois agriculture, the capability to exploit technological changes is critical. When this capability functions rapidly and effectively in agriculture, it can significantly enhance the well-being of the vital farming sector of the Illinois economy.

Steven T. Sonka, professor of farm management and production economics ☐

Rural Communities in an Urban State

Andrew J. Sofranko
and David L. Chicoine

The current financial crisis in agriculture is casting a broad shadow across rural America and throughout much of Illinois. The accompanying predictions are as dire as any heard for decades. Images of the struggles of the 1930s have surfaced to reawaken concerns about the implications of the present crisis. Will the structure of agriculture be altered? What will be the consequences for rural communities? How will rural social relations and farm families be affected? What will be the impact on economic sectors depending on and servicing agriculture?

Change in itself is certainly not new to agriculture nor to rural communities. For the larger part of this century, farming areas of Illinois and the nation have adjusted to numerous economic and technological shifts. Social, economic, technological, and demographic forces have converged to become a catalyst for tremendous diversification in much of rural America.

Because of these changes, the present farm financial crisis is taking place in a rural environment that is vastly different from the one that existed before World War II. Rural Illinois today is not the rural Illinois of yesterday, and thus the ramifications of today's restructuring are different from those of the past.

The "agricultural crisis." Although the agricultural scene has changed, the attention being given to the effects of the current restructuring expresses concerns similar to those voiced several decades ago. We have a replay of familiar historical themes. Farmers are leaving agriculture. Farms are becoming fewer and larger, and an exodus is occurring of farmers and their families from the countryside. Because of these changes, rural institutions are pressured, and rural economic activity is declining. Some rural communities have continued to lose their viability.

Recently, rural sociologist Paul Lasley outlined many of the forces affecting rural life. The structure of agriculture, he argues, is changing because of the financial crisis on the family farm. Not only are there fewer farms, but dual agriculture has become more pronounced.Thus the number of small and large farms has increased, but the number of middle-sized farms has decreased.

Other results of the farm crisis are as follows: further separation of land ownership and labor; increases in tenancy and sharecropping; shift in the control of agriculture to interests outside the immediate rural community — to investors, speculators, and financial institutions.

The current crisis has heightened concern for rural social relationships, for support and service sectors linked to farming, and, perhaps more importantly, for the individuals and families directly implicated in the present crisis. In fact, the struggles of farmers and their families have drawn much attention and have led to the creation of services such as "Rural Route." Such services address the human dimensions of the current crisis.

Rural change and diversification. Many of the expected farm-level impacts described above are real. However, the extent to which on-farm changes will affect rural areas depends on the importance of farming in the local economy. In many regions, agriculture is no longer the dominant economic and social force. Several rural areas have experienced substantial economic diversification during the last decades.

Since World War II, agriculture has steadily declined from a position of dominance in most rural economies. The decline is reflected in the number of farms, the size of the farm population, and the proportion of farmers and their families constituting the rural and total populations.

The rural nonfarm population has increased as new job opportunities have been created via rural industrialization. Extended job opportunities have allowed farm and nonfarm women to enter the labor in record numbers. The emergence of the unexpected urban-to-rural migration "turnaround" in the late 1960s altered the social composition of most rural areas.

It is obvious that the forces affecting rural America have changed Illinois significantly over the past several decades. However, not all Illinois counties have changed to the same extent, and consequently, great diversity is now found across the state. And despite change, rural areas continue to lag behind urban areas in terms of economic and quality-of-life measures.

Collectively, the economic and social diversification has profoundly altered the context in which the present farm financial crisis is occurring. A major difference between what is taking place now and what happened in the earlier decades of this century is that the farming base being affected is not nearly as large as it was; nor are all rural communities and rural people as symbiotically tied to agriculture as they once were.

Rural economies have diversified to the point where for many communities agriculture is no longer the only means of livelihood. In 1940, farming and natural resource industries such as mining and forestry provided more than 4 jobs nationally out of every 10 in rural areas; in 1980 they provided fewer than 1 job in 10. By 1980, farming had become a minor partner in the economy of many rural areas. Service-producing industries, manufacturing, and construction had come to dominate economic activity in a large number of rural areas much as they do in metropolitan areas. As a result, it has become more difficult to predict the extent to which the current farm crisis will affect the rural community as a whole. Much will depend on the extent to which an area relies on agricultural production and income as an economic base.

Despite the overall trend, in many areas production agriculture and the

Table 1. *Agriculture-Related Employment in Selected Multicounty Agricultural Trading Regions*

State of trading region	Typical farm enterprise	Farm sector[a]	Agribusiness: Input services	Agribusiness: Processing[b]	Food & fiber, wholesale & retailing	Total
		Percent of total employment (1979)				
Arkansas	Soybean-rice (irrigated)	8.8	1.3	6.8	8.1	25.0
Illinois	Corn-soybeans	8.5	2.0	2.9	9.2	22.6
Iowa	Pigs-corn-soybeans	8.5	5.0	4.5	8.9	26.9
Kansas	Wheat-alfalfa-sorghum	9.2	1.9	3.2	9.0	23.3
Minnesota	Corn-soybeans	17.8	3.2	7.6	9.7	38.3
Mississippi	Cotton-soybeans	16.2	1.7	3.7	7.6	29.3
Montana	Wheat-barley-fallow	17.6	2.9	1.6	9.1	31.2
Nebraska	Sorghum-wheat-alfalfa	15.6	3.3	4.9	8.9	32.7
North Dakota	Wheat-fallow-barley	19.9	2.3	3.0	8.8	34.0
Texas	Cotton (irrigated)	11.0	1.6	3.3	9.3	25.2
Washington	Wheat-fallow	12.1	1.3	2.3	10.2	25.9
North Carolina	Tobacco	14.6	2.3	9.8	7.2	33.9
U.S. (1982)	All	2.7	3.8	4.9	10.1[c]	21.5

[a] Includes farm proprietors and wage and salary workers.

[b] Includes processing of natural fibers for apparel and textiles.

[c] Includes food service and distribution.

Sources: (1) Petrulis, Minday F. 1985. "Effect of U.S. Farm Policy on Rural America." *Rural Development Perspectives* (June):31–34. (2) Penn, J. B. 1985. "The Agricultural and Rural Economy." *The Dilemmas of Choice.* Washington, D.C.: Resources for the Future, 23–45.

rest of the food and fiber sector are still an important source of employment (Table 1). Nationally, when farm production was linked backward to input services (such as chemicals and equipment) and forward to processing and food wholesaling and retailing, the food and fiber system accounted for 21.5 percent of total labor employment in 1982. However, employment in the food and fiber sector ranged up to 38.3 percent of total employment in the more farm-dependent, multicounty trading regions.

The current agricultural restructuring will directly affect employment in farm production and farm machinery retailing and other input sectors. Little direct effect is expected in the wholesaling sector although some indirect effects will occur in retail food employment. When farm incomes and farm populations decline, the retail trade sector of farming-dependent communities will contract and adjust accordingly.

Farming-dependent areas. Over the years, many rural areas have evolved away from an agriculturally dependent economy toward economies based on manufacturing, government employment, recreation-tourism, and so on. Nationwide, less than 30 percent of the nation's 2,443 rural counties are "agriculture-dependent," that is, derived 20 percent or more of total personal income from production agriculture during the 1975-79 period. Counties dependent on agriculture are located mainly in the Corn Belt and Great Plains states. In Illinois, 30 counties among the 82 nonmetropolitan counties (that is, 36.6 percent) are farming-dependent (Fig. 1). With few exceptions, this set of counties cuts directly across the central part of the state.

Nonfarming economies. The increasing importance of manufacturing and service-related industries in rural Illinois is reflected in the fact that 18 counties are classed as manufacturing economies and 21 counties as diversified. In addition, 7 rural Illinois counties depend heavily on mining, 3

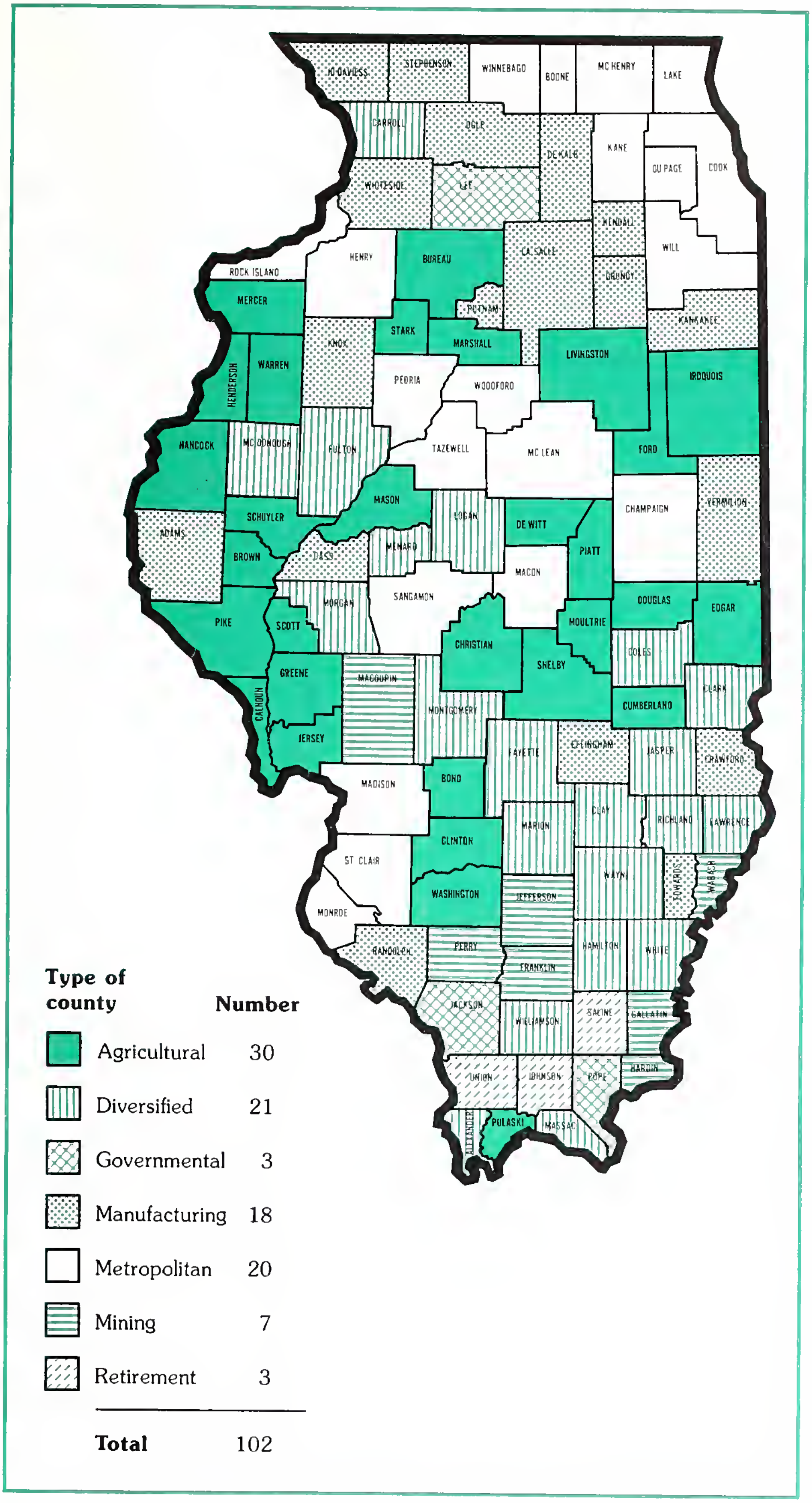


Fig. 1. Illinois counties characterized by type of economy.
Adapted from USDA Economic Research Service, memo from L. D. Bender to M. K. Nelson, September 21, 1984.

mostly on government institutions, and 3 others on transfer payments and retirement incomes. The last category contains counties with a large population of senior citizens. This diversification took place across Illinois not because agriculture declined but because nonagricultural sectors grew much more rapidly.

A look at the future. To argue that farm trends have not had an impact on rural areas or will not continue to do so in the future is to ignore substantial evidence to the contrary. It is equally nearsighted, though, to argue either that past trends and impacts are presently being repeated or that agriculture is the preeminent economic force for change in *all* rural areas. The rural nonfarm sector has demonstrated a surprising viability and strength. It has attracted business activity, people, and nonfarm jobs. All of these myriad changes have dramatically and irreversibly altered the economic and demographic character of much of rural Illinois.

Agriculture has always had an impact on rural communities — on their economic life and growth. It continues to do so, but this impact has diminished over the years, particularly in certain regions. In the early 1980s, relatively fewer rural jobs were agriculturally related, nonfarm jobs greatly outnumbered farm jobs, and even many farmers had become dependent on off-farm employment for much of their income. Over the years, forces other than agriculture have come to play a major role in the lives of rural people and rural communities across Illinois. The performance of service-related industries and manufacturing, and the economies of smaller urban centers scattered across the Illinois countryside now combine with production agriculture to shape the future of rural Illinois.

Andrew J. Sofranko, professor of rural sociology and David L. Chicoine, associate professor in the Department of Agricultural Economics and the Institute of Government and Public Affairs ☐

Farming Communities in Transition

Sonya Salamon

The current agricultural crisis is affecting rural society in many ways. It is predicted that because of the crisis, Illinois will lose one-third of its middle-range family farms. This dramatic change will accelerate the long-term rural social trends that are already evident: a decline in the population actually farming and a deterioration of small communities economically dependent on agriculture.

We will undoubtedly see more consolidations of churches and schools, those institutions pivotal to the maintenance of a rural community's identity, vitality, and integration. As more men and women leave farming, or take off-farm work to supplement farm incomes, they will not be able to give the time and commitment crucial to sustaining a rural community. For instance, in the past, women now in the labor force differentially provided vital family services, such as care for young children and the elderly. Consequently, a network for social exchange functioned to link community households.

Ethnic differences. Because the trends under discussion are not new, we have already seen how Illinois communities have responded to such challenges in the past. Ethnic origin and traditional values shape the responses that a community makes to preserve its viability. This fact is evident when we observe the differences among villages located within an area that is otherwise similar. Although the farms and soils are comparable, communities even side by side will differ in their reactions.

German ethnic groups are committed to farming as a way of life and view the continuity of the family farm as being integrally linked to the viability of the community. These groups actively participate in local activities and volunteer work. Other ethnic groups focus more on individualism and personal enterprise. They do not feel that community participation contributes to those priorities. For such groups, farms exist independently of the community in which they are located. A village death is viewed mainly as an economic failure. Because these communities make no concerted effort to counteract local decline, they are more likely to fade.

Adjusting to change. Two factors that play a part in making rural life attractive are the open spaces and the self-reliance that country living fosters. These same factors, however, complicate dealing with the current situation. As employment on farms and in local institutions disappears, the distance from farmstead to work place will increase. Rural residents will have to travel farther to seek employment.

As rural schools and churches close, innovations at the local level will be necessary to bind the community together. Those communities that have more successfully held on to their young families — a community's future — have restructured their integrative institutions. They have thus been able to unify a populace separated by far-flung commuting.

Care of the very old and young presents particular family problems since women of all ages now work outside the home. Some communities have provided day care for preschool children, so young working families who might otherwise leave can still remain in rural areas.

In the future, communities will have to go further to provide support services. For example, day care could be arranged for the elderly. Such services could be organized at low cost and housed in the churches, abandoned schools, or business buildings standing in most villages. Family-centered services would draw people and volunteers into town daily and create the cross-generational bonds and face-to-face interactions that integrate communities.

Ethnic groups that have produced such local support have continued to sustain viable communities while experiencing rapid change. Royal, a village of 274 inhabitants in Champaign County, was recently presented with the Governor's Silver Cup Award for its involvement in community services. The residents, who are ethnically German, built a community center, using volunteers. All the materials and labor for the building were donated.

Villages will have to reinvent themselves by creating new institutions. Perhaps the answer to rural fragmentation is a community that acts as the large, extended farm family of the past. Such a community could provide functions that can no longer be managed by individual households.

Sonya Salamon, associate professor of family relationships ☐

Women's Voices

MaryAnn Paynter

Our current social and economic climate is redefining the role of women in Illinois agriculture. At present, many women seem fairly satisfied with farming as a way of life. Yet many are not satisfied with farming as a means of livelihood.

In the winter of 1985 a regional research project was undertaken that focused on farm wives and their families (S-191 study, "Farm Wife's External Employment, Family Economic Productivity and Family Functioning"). As part of this project, researchers mailed questionnaires to male and female farmers in Illinois. The respondents identified many concerns that have also been found in a nationwide USDA study. This discussion will focus on the concerns of Illinois women as expressed in their responses to the questionnaire.

It is evident that women wanted to maintain their chosen lifestyle and continue their family-farm business during this period of economic uncertainty. Some of their responses are given in the box.

Some responses of Illinois women to life on the farm

- "Answering this . . . reminded me of how my marriage really is."
- "The farm's a great place to live."
- "It takes a special personality to be married to a farmer. A woman has to be a hard worker, willing to get dirty, put in long hours — 24 hours each day with her spouse. Some of us give men so much that we forget to give to ourselves . . . but it's not all bad — it's good that farm families are so close."

On-farm responsibilities. At the national level, the USDA survey indicates that farm women spend about two-thirds of their lives on farms. Almost half of them regularly do bookkeeping, raise food for the family, and run farm errands. Many are involved in other tasks, including field work. One Illinois woman worked as a field hand to help raise a large family and "retired" only when her youngest son decided to farm.

Yet much of what women do in agriculture seems to go unrecognized. "Give us farm wives a little credit for all we do," pleaded one respondent, "I'm the cheapest hired hand my husband has." She also said, "But I'd hate to give it up."

Off-farm employment. About one-third of farm women are employed off the farm. One-fourth report that they work to provide money for the farm. One Illinois respondent made this observation in the S-191 study: "The reality that this farm will not create enough income for our family to just survive is hard to accept, but I think we all have to face this right now. Down the road, I hope for improvement or no one will farm."

Another repondent said, "It's upsetting to be in need of off-farm jobs — they increase stress in a family. Farming is an honorable profession — we should be able to make a living at it. . . . If something isn't done to correct farm prices in comparison to expenses, you're not going to have to worry about farmers because there aren't going to be many around. It's terrible to have the investment we have in land and machinery and barely make a living!"

Many respondents wrote about the need for lower interest rates and for increases in crop and livestock prices. These requests, if granted, could change farming for both men and women.

In some other areas, changes will specifically affect women. For example, education and information programs, such as those provided by the Cooperative Extension Service, will be better designed to include women.

Need for recognition. Many changes must be made to more widely recognize the valuable and often crucial roles played by farm women. Although many females labor for years to build and preserve a farm, they are seldom given operator status. One respondent remarked, "You would be surprised at the number of women who will not marry a farmer; . . . he feels that the farm is his. He may say it's ours, but when the will is made, it's a different story." Because of this, some Illinois respondents seek to continue changing legislation related to inheritance laws and estate taxes.

Women on farms have been frequently stereotyped. They are often categorized by the Census Bureau as "unpaid family labor." They are also referred to as independent producers, partners, not operators, farm wives, and helpers. If women are to continue playing essential roles in the agricultural development of the state of Illinois, they must receive the recognition they so justly deserve for their work.

MaryAnn Paynter, extension specialist, family economics ☐

Trends in Animal Agriculture

Richard E. Dierks
and David H. Baker

Dramatic changes have occurred and continue to occur in many sectors of American agriculture. An area greatly affected by change is animal agriculture. Short-term trends in prices can cause extreme fluctuations in the profit or loss of a production system. The current drop in crude oil prices of almost 50 percent during the past six months, for instance, will have a major impact on this year's farm production costs. This article will, however, largely ignore short-term trends and will focus on current and projected long-term trends in animal production systems.

Almost 70 percent of this country's total agricultural area is range and pasture land. The available photosynthetic energy captured by grasses and forages must be processed through livestock if it is to be used for human nutrition. About 87 percent of the corn crop, 70 percent of the soybean crop, 21 percent of the wheat, 95 percent of grain sorghums, and most of the oat, barley, and rye crops are currently fed to livestock.

Of the food-source photosynthetic energy used to feed humans, about 87 percent comes from animal products. Annual livestock sales account for about $70 billion or 50 percent of the sales value of agricultural products.

Changing food habits. The lifestyle and eating habits of people in the United States are playing a significant role in how meat, poultry, and dairy products are produced, processed, and served. The trend of eating meals outside the home continues to increase. According to the most recent statistics, 34 cents of the farm-value food dollar were spent for food consumed at home, whereas only 17 cents were spent for away-from-home consumption. Another way of stating this fact is to say that if chicken or hamburger is purchased in the supermarket and eaten at home, 66 percent of the consumer's total expenditure goes toward marketing costs. On the other hand, if that meat is eaten as McDonald's Chicken Mcnuggets or a Big Mac, 83 percent of the consumer's expenditure goes toward marketing costs.

Public opinion about the long-term effects of meat, poultry, and dairy products on health is an important element to be considered. Changing attitudes are reflected in the demand for certain products, for example, meats with a lower fat content. On a per capita basis, Americans are consuming less red meat and fewer eggs because they are concerned about saturated fatty acids and cholesterol. They are also demanding more lean meat and less fat in their meat and dairy products.

Trends in production. Production agriculture in Illinois is a way of life, but it must become more efficient to survive. Efficiency can be most easily increased through automation and by expanding the total size of the operation because, under these circumstances, the cost per unit of production decreases.

Nationally, long-term trends indicate that poultry consumption will continue to increase, largely at the expense of beef consumption. Pork consumption is projected to remain relatively constant, with only a small increase through the year 2000. The trend toward larger units production will continue.

Swine production has changed in recent years. In the early 1970s, approximately 1 million farms produced swine. Today that number is down to about 200,000. Some industrial leaders are predicting that by the year 2000 the number of swine farms will decline further — to number between 5,000 and 10,000. Since pork consumption is projected to remain constant, the decrease in farm numbers will be accompanied by a striking increase in farm size. In fact, the swine industry is moving rapidly toward large, integrated production systems. The trend is not unlike that which has occurred in the broiler industry over the past 20 years. The swine industry in Illinois should continue to prosper because it has the advantage of being located near the center of the nation's corn and soybean production; because markets are accessible; and because transportation is well developed.

Beef cattle are raised on range or pasture land that is deficient in rainfall or is too hilly to be used efficiently for grain production. The animals are then moved to feedlots to complete their growth and finishing for market. The movement in beef production is certainly heading toward larger feedlot operations located primarily outside the Midwest.

Consumption of *dairy products* is at present considerably below the dairy industry's production level. It has been estimated that over the next two to three years dairy cattle numbers must be reduced by 20 percent in order to balance production and consumption.

Biotechnology has produced a growth hormone that increases milk production as much as 40 percent. When this technology is applied widely in the dairy industry, the number of cows will decline even further. However, the size of individual dairy units is likely to increase, bringing down the cost per unit of production.

Cheese consumption continues to rise, but this rise is offset by the lower per capita consumption of milk, cream, butter, and other dairy products.

Long-term national trends indicate that *poultry* consumption will continue to increase. In Illinois, however, the numbers produced have decreased. The scale of Illinois broiler- and egg-production units is small compared with those in the southern states. Nevertheless, some experts predict that integrated, large-scale broiler production units may move to Illinois from the south. Two factors could propel Illinois into developing large-scale, integrated poultry production units: (1) rising transportation costs and (2) the accessibility of

Swine raised on the University [illegible] veterinary students about [illegible] and [illegible] are also being used in research projects [illegible] infectious diseases.

feedstuffs. Illinois is more favorably located than the southern states in relation to the major consumption areas. Thus, products will be transported over shorter distances. In addition, Illinois produces the largest amount of corn and soybeans for feed.

The number of *sheep* continues to drop, both in Illinois and nationally. Production of other minor species (such as goats and rabbits) will probably continue only for specialty markets.

Improving production efficiency. Animal production systems vary a great deal in their efficiency. Those who survive in the future will be those who have improved their efficiency. Nationally, annual losses from low performance are estimated at $10 billion to $14 billion, or 14 to 20 percent of the total income from U.S. animal agriculture.

Research is an important element in production efficiency. An improved twinning rate in beef cattle, a shortening of the calving interval for dairy cattle, and better embryonic survival in swine all translate into millions of dollars of profit. Artificial insemination has improved the beef and dairy industries tremendously. Research on superovulation, predetermination of sex, *in vitro* fertilization, and embryo transfer can enhance the efficiency of livestock production.

Disease prevention and control also play a significant role in production efficiency. Disease losses cost livestock producers an estimated 20 percent of their income from livestock and poultry products. Nationally, these losses are estimated to be over $17 billion. In Illinois, animal losses from infectious diseases, internal and external parasites, and toxins cost approximately $100 million per year. Effective management should key on prevention as a primary means of reducing these losses.

Recent surveys by the USDA National Animal Disease Detection System in two midwestern states indicate that over 80 percent of the cattle or swine produced are not seen by veterinarians in the period from birth to market. Only about 10 percent of the producers are practicing effective disease prevention techniques as part of their management procedures. Some producers use antimicrobials and vaccines indiscriminately. This practice hurts rather than helps prevention and, additionally, is ineffective in treating animal diseases.

In the future, veterinarians, researchers, and food animal producers together must develop more effective disease prevention programs based on economically sound management practices. Disease *treatment* can only minimize losses, whereas disease *prevention* will help maximize profits.

Better systems are needed for animal-production records. These will be effective not only for managing disease prevention, but also for other management decisions, such as the selection of desirable sires and dams.

Companion animals. Cats, dogs, birds, tropical fish, other domestic pets, and horses are an integral part of both rural and urban societies. An estimated 80 percent of

all households in the United States own some kind of pet. Expenditure for the health care of companion animals and horses accounted for 82 percent of the $4.6 billion spent in the United States for veterinary services in 1982. And 55 million bushels of corn and 37 million bushels of soybeans were used to manufacture dry dog food alone.

The affection people have for pets is evident in many situations, ranging from the family setting to the institutional environment. Pets have proven to be therapeutic for the aged in retirement homes, for handicapped children, and even for incarcerated adults. Companion animals return an undemanding love that is often needed in our rapid-paced society. Pets will continue to fulfill an important human need in the future.

Animal rights issue. Feelings for animals are increasingly being expressed in other ways. Several organizations have been created for animal rights and animal welfare, and their number is growing. Many of them are well-funded as well as politically astute; their members express attitudes toward a wide spectrum of issues ranging from production activities to animal research. The most active advocacy organizations are very willing to break laws and even steal research animals to draw the attention of governmental agencies and the public to what they believe are abuses. These same organizations are attempting to influence legislation that will restrict the use of animals in various research activities.

Some of these organizations object to several confinement-rearing practices that are used in modern production systems. We should not simply dismiss animal rights advocates as misguided cranks. They are generally articulate, dedicated individuals with a deep sense of conviction. Those of us involved in animal agriculture should be aware of the issues. In addition, we should provide excellent animal care. We must be willing to examine and defend our production practices as being in the best interests of both the animals and their owners. If not, we must be willing to change.

Biotechnology in animal production. Biotechnology is just beginning to be applied to animal production systems. The first application was the genetic engineering of vaccines for treating colibacillosis (scours) in calves. Since then, a subunit vaccine has been genetically engineered for foot-and-mouth disease in cattle. This vaccine will be used in Africa, South America, and the Far East — where the disease is a major problem — rather than in the United States. Other vaccines and diagnostic reagents will be developed that will benefit both domestic and foreign livestock populations.

The gene providing for the coding of protective antigens against the rabies virus has been incorporated into a vaccinia (pox) virus for use in dogs. The vaccinia virus not only introduces the rabies antigen into the dog, it also creates a more long-lasting immunity against rabies. This technique can be used to prepare many other animal vaccines. Monoclonal antibodies — a fusion product of plasma cells and a tumor cell — are being utilized both in the diagnosis and treatment of specific diseases.

The effectiveness of bovine somatotropin (growth hormone) in increasing milk production in dairy cows has been proven experimentally. It is anticipated that this product will become available commercially by 1987 or 1988. Experiments with growth hormone promoters have indicated that animals secreting high levels of their own growth hormone may grow faster and more efficiently and deposit less body fat. Many animals marketed at a relatively young age, such as swine and poultry, may be produced more profitably through such techniques.

The earliest wave of products created through biotechnological techniques will involve monoclonal antibodies and those vaccines, antigens, hormones, and other protein products that are produced in bacterial, viral, fungal, or tissue-culture systems.

Microbial manipulation has the potential to alter microorganisms in ruminant digestive tracts so that they might effectively ferment and break down roughages with high cellulose or lignin contents. Deer and water buffalo eat and gain weight on brush and forages that would not sustain our domestic breeds of cattle. Studies of rumen microflora in these species could prove very valuable. They would help researchers determine whether it is the rumen flora or other genetic factors that give deer and water buffalo the capacity to utilize such roughages efficiently.

Specific genes can be mechanically transferred from one animal to another, but at present very little is known about the regulation and expression of genes in mammals. More research will help identify these mechanisms and determine how they can be used to transfer desired characteristics to other food-producing animals. A research project is under way at the Urbana-Champaign campus to transfer superior characteristics from imported Chinese pigs into domestic swine. Among the desired characteristics are prolificacy and genetic resistance to disease.

Biotechnology will also be developed both to create value-added features for meat products and to enhance their marketability. For instance, improved strains of lactic acid producing organims are being developed, which will eventually improve the quality of summer sausage.

Improved management, advances in integrated herd-health-data systems, improvements in environmental conditions, the study and elimination of adverse chemical and toxic substances, and the application of biotechnology offer unparalleled opportunities for rapid advancement in animal agriculture. The application of many of these processes will, in the years ahead, require much closer collaborative ties between university faculty, governmental agencies, industrial firms, and farmers.

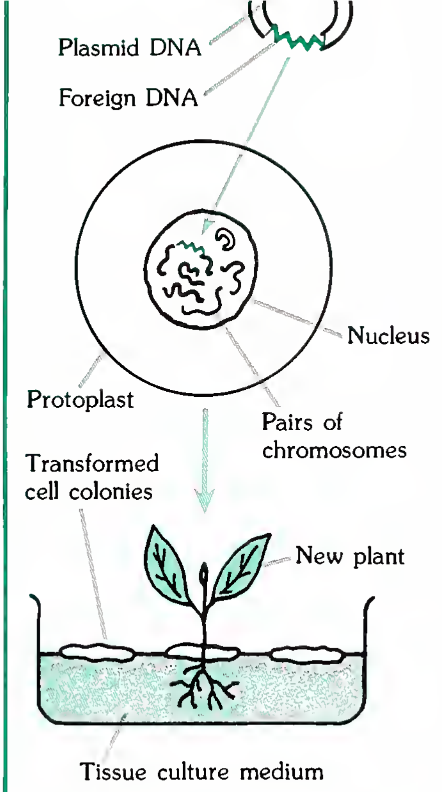
Richard E. Dierks, dean of the College of Veterinary Medicine and David H. Baker, professor of comparative nutrition, Department of Animal Sciences ☐

Plant Agriculture of the Future

Larry E. Schrader

Technology will have an enormous impact on plant agriculture in the future. Biotechnology is advancing rapidly and will add an important new dimension to crop improvement. For example, desirable genes from wild species and other plant species and genera will be introduced into crops that cannot be crossed naturally by conventional plant breeding techniques. As a result, genetic variability will increase. Furthermore, biotechnology will permit desired traits to be introduced into plants. These traits include greater resistance to diseases, insects, herbicides, and environmental stresses. Because many of these traits are controlled by single genes, they can be modified by genetic engineering much more easily than complex traits (such as yields), which are controlled by multiple genes.

For decades, plant breeders have introduced genes into crop plants to improve them, but the procedure takes many years. Frequently, several undesirable traits accompany the desired trait; thus yields might increase but the new variety may be susceptible to a disease. Many generations of backcrossing are then required to eliminate the undesirable traits.



Gene splicing. Foreign DNA that codes for a desired trait is spliced into a plasmid vector. The plasmid is introduced into the nucleus of a protoplast, a plant cell after the cell wall is removed. Foreign DNA becomes incorporated into the DNA of the protoplast. The cell with foreign DNA forms a cell colony, regenerating into a new plant.
Reprinted from *Il. Res.*, v. 25, no. 4.

Cell culture and gene splicing. Many crop species cannot be crossed by conventional techniques. Tissue culture and cell culture have advanced to a stage in which virtually any line of corn or soybeans can be regenerated from a callus (clump of cells). Cells can be transformed to contain the desired genes, and then plants with the desired traits can be regenerated. These cell-culture techniques also provide a rapid means of screening cells to detect their resistance to diseases, herbicides, or environmental stresses such as salt accumulation and temperature extremes. Cells that survive the screening can be regenerated into whole plants.

Gene splicing will improve nutritional qualities in crop plants. For example, the composition of seeds can be modified to improve the amino acid balance of proteins. Most crop species contain insufficient quantities of certain amino acids (e.g., lysine, methionine, and tryptophan) to meet the nutritional requirements of humans and animals. Through biotechnology, these amino acids will be increased to a desired level.

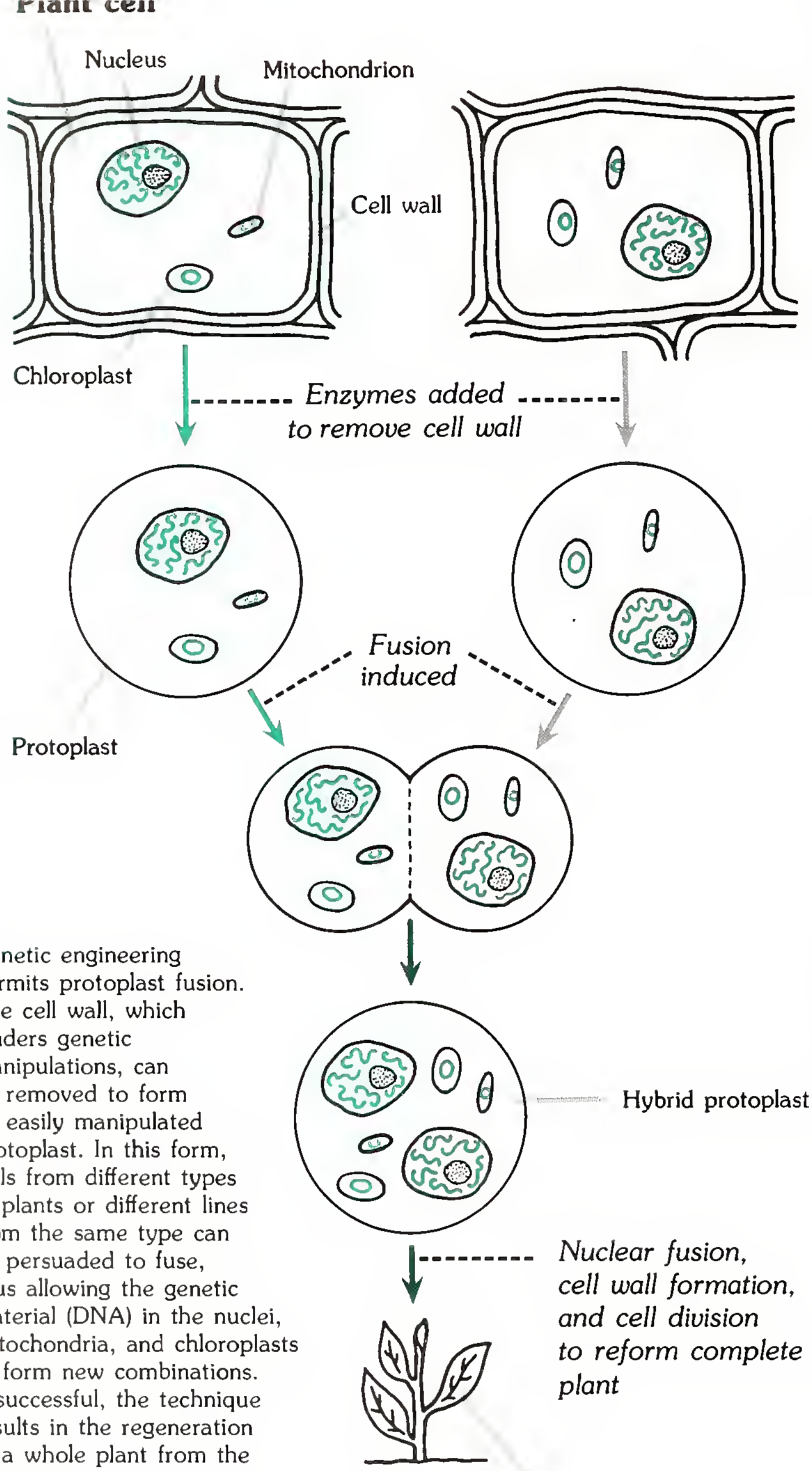
Antinutritional elements, such as the Kunitz trypsin inhibitor, will be eliminated from soybean seeds. This inhibitor interferes with the digestibility of soybean seed proteins. Here in the Department of Agronomy, Theodore Hymowitz and Richard Bernard recently developed three soybean lines that are free of the Kunitz trypsin inhibitor. Elimination of this and other inhibitors will save processors the millions of dollars that they currently spend on heating soybeans to eliminate these inhibitors.

Genetic engineering will permit the incorporation of resistance to certain herbicides. Broad spectrum herbicides will be used to kill all plants except crop species that are resistant to the herbicides. For example, experiments are in progress to transfer glyphosate resistance into soybeans. The development of herbicides and other pesticides that biodegrade more rapidly will be increasingly emphasized. In fact, a photodynamic herbicide is already being developed by Constantin Rebeiz, professor of plant physiology in the Department of Horticulture.

Specialized crop production. We will see an increase in crops that are more specialized for particular commercial uses. Crops with particular traits such as high protein, high oil, or high starch will be developed because they improve milling quality. In addition, the amount of product generated per unit processed may increase, and the overall quality of the product may improve.

Until grain buyers and processors pay a suitable premium for a higher quality product, farmers will not adopt crop varieties with improved quality. Frequently, crops whose quality is modified have a lower yield than regular crops, so growers must be given a premium as incentive to grow these crops. A good example is high-lysine corn. Even though this corn is nutritionally superior, farmers have been slow to adopt it because yield is frequently reduced slightly and no premium is normally paid to offset the yield loss.

Grain handlers and buyers have been slow to encourage adoption of new varieties because they will need additional labor and equipment to keep the higher quality product separate from the normal product. In the future, however, we will see more contracting. Processors will



Genetic engineering permits protoplast fusion. The cell wall, which hinders genetic manipulations, can be removed to form an easily manipulated protoplast. In this form, cells from different types of plants or different lines from the same type can be persuaded to fuse, thus allowing the genetic material (DNA) in the nuclei, mitochondria, and chloroplasts to form new combinations. If successful, the technique results in the regeneration of a whole plant from the hybrid cell.

Reprinted from *Il. Res.*, v. 25, no. 4.

contract with growers for a quality product for specific uses. This already occurs to some extent with white corn, potatoes, and high protein oats. Processors are recognizing that a higher quality raw material results in a better product and greater profitability.

Genotype protection. Biotechnology will be useful to plant breeders and to the seed industry for protecting the genotypes developed. A technique referred to as "restriction fragment length polymorphism" will be useful to identify a genotype and to protect the proprietary rights of plant breeders. This technique can be used to test for outcross contamination in seed lots. It will save considerable time as it eliminates the need for field testing to identify these outcrosses. It will also be useful in establishing maps of genes and their linkages.

Molecular diagnosis. Another useful spinoff of biotechnology will be the development of molecular diagnostics for detecting diseases in plants. This technique will make it possible to detect the presence of disease-causing organisms and viruses before symptoms appear.

Biological control. This means of control will become more important as it is better understood. Perhaps genetically modified mites and other organisms will be released to literally eat other pests that live on plants. Bacteria are being developed to suppress insect pests just as chemical insecticides suppress insects. The "microbial insecticides" produce substances that are toxic to certain insects, but safe for beneficial insects and warm-blooded animals. For example, *Bacillus thuringiensis* produces a crystal toxin that kills insect pests quickly. This bacterium is already used worldwide. Others are being developed. Fungi too are being developed for biological control.

Genetically engineered bacteria will prevent frost on high-value crops. Although some genetically engineered organisms are available today, existing regulations forbid field testing and so prevent their release into the atmosphere.

The morphology or structure of leaves and other plant parts may be modified in the future to make these plant parts less susceptible to predators and organisms carrying diseases. It is known that some plants (e.g., alfalfa and quackgrass) excrete compounds that are allelopathic. That is, the excreted compounds inhibit the growth of other plant species. If crop plants can be engineered to excrete substances that inhibit weed growth, fewer herbicides will be required for weed control. Reduction of herbicide usage will decrease costs and also benefit the environment.

Growth and yield regulation. Current basic research in agronomy will enable researchers to discover important processes that limit crop yields. Researchers will identify the processes that limit photosynthesis, nitrogen fixation, and other important metabolic pathways. As the genes regulating these processes are in turn identified, genetic engineering will be used to insert and express the desirable genes. The end result will be that crop plants will improve in efficiency. Thus input costs will decrease and in turn lower the cost per unit of production.

We will probably see expanded use of plant growth regulators on certain crops. The extent to which they are adopted will depend in part on whether they are approved in the United States. Certain plant growth regulators in other parts of the world are used to shorten plants and make them less susceptible to lodging. For instance, a growth regulator used in Europe restricts the height of wheat, permitting application of high levels of nitrogen fertilizer to obtain high yields. Plant growth regulators could also be employed for other purposes. Researchers are applying the concept to increase the proportion of plant dry matter allocated to grain production. One strategy would be to develop corn plants in the future with multiple ears per plant. Growth regulators may also be used on lawns to reduce the growth rate of grasses and thus diminish the frequency of mowing.

Hydroponics. This technique will provide a year-round supply of fresh vegetables in northern states. Large northern cities such as Chicago annually ship in over 90 percent of their fresh produce. The Archer Daniel Midlands company in Decatur is already growing vegetables in a large greenhouse that uses heat and carbon dioxide released in part from soybean and corn processing. Comparable operations can use other by-products in a similar fashion. Adoption of hydroponics reduces the transportation costs normally required to move fresh vegetables and fruits over long distances during the winter.

Postharvest physiology. More attention will be given to this area of research, especially to fresh fruits and vegetables that cannot be grown hydroponically and must be shipped long distances. As the processes of ripening are better understood, new hormones or chemicals will be applied to produce fruit that ripens uniformly. Thus the final product will be higher in quality, more attractive in appearance, and easier to store.

Other advances. Changes will occur in tillage, agronomic production, and management practices. New tillage methods that conserve soil and energy will become widespread. Farmers will become better acquainted with techniques that minimize soil compaction, runoff, and loss of chemicals and nutrients by leaching. The Conservation Reserve Program, approved by Congress in 1985, will enhance farmers' awareness of soil conservation and erosion control. Farmers will be encouraged to set aside millions of acres in this reserve program.

In the future, computers and microprocessors will become commonplace on the farm. Farmers will use expert systems widely in decision making. Computers and microprocessors will be linked to sensors that monitor crop harvesting and other farm operations. Sensors on combines will help farmers detect the moisture content of grain during harvest. Other sensors will monitor the drying rate of grain to minimize energy consumption. Microprocessors will control the application of chemicals and fertilizers. And sensors located in the fields will help determine when irrigation is needed.

Policies and regulations. Policy decisions and new regulations will affect plant agriculture in the future. The field testing of genetically engineered microorganisms and plants illustrates the point. These microorganisms were available two or three years ago, but field testing has not yet occurred. If the regulations and laws are not changed, the benefits of biotechnology will be delayed and perhaps even diminished. Specifically, certain regulations prevent the field testing of bacteria that help protect plants from frost. This treatment has great potential for certain high-value crops, such as strawberries.

It is becoming extremely important to develop crop plants with more tolerance to insects, diseases, and weeds because pesticide usage is becoming increasingly restricted. If pesticide usage can be reduced further, production costs will be decreased.

Stricter regulations are likely to further restrict fertilizer application. The purpose of these regulations will be to control the amount of leaching into ground water and streams. Rising costs may also inhibit the use of fertilizers. However, new research will generate crop varieties that are more efficient in absorbing and metabolizing minerals absorbed from the soil. Technology for applying fertilizer and other nutrients to the soil more precisely will reduce costs and greatly increase efficiency. More extensive use of fertilizer spreaders with computerized controls will permit the application of those elements specifically needed for smaller areas of the farmer's fields. Although these custom-made applications will require more extensive soil testing, they will use fertilizers more efficiently. They will also be less dangerous to the environment. Slow-release fertilizers will decrease losses of nitrogen by leaching, nitrification, and denitrification. More effective nitrification inhibitors will be developed that will reduce all three of the losses listed above.

Although agriculture is going through a difficult transitional period, the future is bright. Much exciting research in the plant sciences is in progress, which will transform agriculture in the next two decades. In this brief article, only a few examples have been cited. Many other types of research are also under way. These are challenging times, and I believe research will lead the way in improving production efficiency. As a result, the cost per unit produced will decline, and profitability will be restored to agriculture.

Larry E. Schrader, professor and head, Department of Agronomy □

Product Use and Marketing Research

Roscoe L. Pershing and Arthur J. Siedler

The food and agricultural research establishment today is facing new problems that place severe pressures on the research system. The current supply of agricultural commodities exceeds demand. For example, we can expect surpluses in corn production for years (Fig. 1). We must find ways to increase the demand for Illinois's agricultural commodities.

American consumers spend over $300 billion annually for food. Approximately 30 percent of that goes toward on-farm production costs. The remaining 70 percent is spent on postharvest activities and marketing. Yet Americans use only 15 percent of their disposable income for food purchases!

The phrase "agricultural postharvest technology and marketing economics" refers to all the technological and economic transformations that agricultural products undergo between harvest and consumption. It includes storage, assembly, processing, packaging, warehousing, transportation, and distribution of agricultural products through the institutional food trade and wholesale and retail outlets.

In total, there are over a million organizations within this system, including retailers, food service establishments, wholesalers and food processors. The system generates approximately 12 million jobs. In other words, 1 out of every 10 U.S. workers is employed in the food trade. Supporting sectors create another 3½ million jobs. This sector of the agricultural system, by its very size, has the potential for much greater economic development.

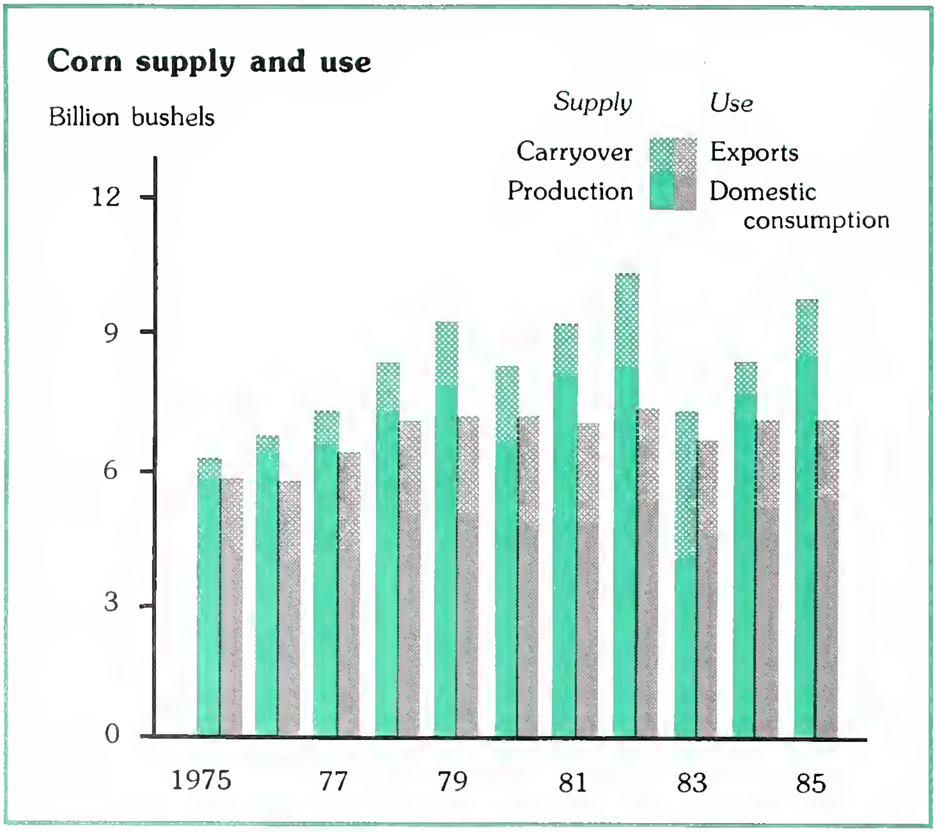


Fig. 1. Corn supply and use, estimated for 1984, projected for 1985. Supply includes imports. Year beginning October 1.
Adapted from 1985 Agricultural Chartbook, USDA Agriculture Handbook No. 652, Chart 235.

Marketing foods and feeds. The U.S. food market is characterized by slow growth. It is labor intensive rather than capital intensive, particularly in food service and retailing. In addition, the market is saturated, except in certain areas. We cannot therefore expect the domestic food and feed market to expand significantly. A possible exception is the fish and shellfish "farming" industry. Here a potential market exists, and domestic products could replace imports.

In general, we must look toward export markets for substantial increases in the demand for agricultural commodities produced in Illinois. In fact, international markets must be nurtured and developed. To gain access to these markets, we must be competitive. We will have to produce highly desirable products that are higher in quality or cheaper than those of our competitors.

New markets. A large potential market for agricultural commodities is one not associated with food or feed use. This is the market for chemicals that are currently manufactured from petroleum sources. Although petroleum prices have fallen, they are likely to recover because petroleum is a nonrenewable resource. Prices may exceed previous highs as demands increase worldwide.

Agricultural commodities can be used to manufacture products for which petrochemicals are currently being employed. The market for these chemicals is large (see box). The chemical feedstocks used in the manufacture of plastics (propylene and ethylene) account for a major portion of the market — over 7 million metric tons per year. Methods to manufacture these chemicals from agricultural commodities have been developed and involve biotechnology.

Value added. A key to market development is exploitation of the "value added" concept. The value of agricultural commodities can be increased via technology. Products can

*Estimated Markets for Agricultural Chemicals**

Chemical	**Metric tons × 1,000**
Acetaldehyde	297**
Acetic acid	350**
Acetone	346
Butadiene	657**
Butanol	243
Ethylene	4,384
Ethylene glycol	429**
Methanol	280
Propylene	2,981
Propylene glycol	205**
Total potential	10,172,000 metric tons

* These chemicals can be derived from agricultural commodities but are at present primarily manufactured from petroleum sources. Based on manufactured product, C&E News, December 16, 1985.

** Some of the chemicals listed may be used in the manufacture of others.

From one bushel of corn . . .

31.5 pounds (14.27 kg) of starch *or*

33.0 pounds (14.95 kg) of sweetener *or*

2.5 gallons (9.46 liters) of fuel ethanol

12.4 pounds (5.62 kg) of 21% protein feed

3.0 pounds (1.36 kg) of 60% gluten meal

1.5 pounds (0.68 kg) corn oil

The products containing corn and the many uses for corn are countless. Adapted, with permission, from a publication of the Illinois Corn Marketing Board.

thus be enhanced in a number of ways. Technology can make the product more stable, more concentrated, more convenient, safer, more nutritious, or better tasting. Technology can also generate more uses for a product than originally conceived.

All of the improvements mentioned above are quality factors. To be competitive, value added must give more quality per unit price than the competition. For example, when corn is processed to yield high fructose corn syrup, a value-added product is created. This value-added factor substantially increases the use of corn. We can improve product utilization even further by generating better or more useful coproducts from the process.

In the Department of Food Science, we have initiated research to increase the value of corn gluten. We are exploring new separation techniques for removing gluten from corn. We expect to formulate product concepts that use corn gluten combined with wheat flours or starches. The products will be processed by extrusion and evaluated for taste and stability. Other comparable projects are under way for soybean, meat and dairy products, fats and oils, and other products. Research pertaining to the utilization of agricultural commodities cannot be overemphasized.

The rationale for increasing our research efforts in postharvest technology is embodied in a statement made by Mary Carter of the U.S. Department of Agriculture in Decatur, Illinois, on July 25, 1983. On appearing before the Subcommittee on Investigations and Oversight — a subcommittee of the Committee on Science and Technology, U.S. House of Representatives — she said "Research can be a catalyst for change, particularly in initiating new phases of corporate growth. It does so by generating new product and process concepts, which can be developed into (hands-on) innovative technologies used by the industrial sector to produce new products, or to increase the efficiency and profitability of existing processes. . . ."

Currently, the major investment in postharvest research is being made by the industrial sector. This research is primarily applied, short-term research. Federal and state support is limited. Less than 15 percent of the USDA research budget is used for postharvest technology and marketing research. Other federal agencies have very limited inputs. Greater investment in postharvest research will benefit producers, consumers, marketing firms, labor, and input suppliers. The range of benefits include the following:

- increased productivity and reduced real cost to produce the final product
- enhanced quality, safety, and nutrient content
- information for market decision-making
- international competitiveness

Value-added research is a needed partner to production research. Working in parallel, these areas of research can increase the demand for Illinois commodities. The following example is a case in point. Many farmers cannot make a profit raising corn for a market price below $2 per bushel. In a saturated market, they have little incentive to lower the cost per bushel by increasing their yields, because prices would fall even further as surpluses increase. However, research that reduces input costs or increases demand would lower production costs without generating surpluses. With lower production costs, more corn could be coverted to ethanol and other products. The market would thus expand, making room for larger yields. Ethanol could then become an economically viable alternative to petroleum fuels. In the Department of Agricultural Engineering, we are testing a farm tractor in the 50 horsepower range that uses 100 percent ethanol fuel.

Moving forward. Several steps are necessary if we are to address the needs of the postharvest sector of the agricultural system.

In *research* we must develop the following:

- a better understanding of the physical, chemical, and biological properties and structures of agricultural commodities

- sensor capabilities to measure the above-mentioned properties rapidly and nondestructively, using continuous (on-line) analysis
- a better understanding of the mechanisms controlling biological activities in order to exploit the full potential of biotechnology
- approaches for using research information to devise new and innovative technologies that will emphasize automation (including robotics) and process control and thus increase our competitiveness

A necessary trade-off for this research is to decrease the labor intensity of the postharvest system so that efficiency will increase. This trade-off will be compensated for by expanding markets, which will increase overall economic development of the total agricultural system.

Human resources are often overlooked, but they are vital to the agricultural system. Highly trained people must be available to adopt new and innovative technologies, develop new uses, and produce value-added products. The university is the primary supplier of these necessary human resources. The future will require not only numbers, but a quality of education that can meet these needs. Without the necessary quality of human resources, our efforts will fail.

An integrated approach. Vitalizing the postharvest sector of the system is necessary for the future success of agriculture. In addition, the two aspects of agriculture — production and utilization — should be integrated into a unified system. A stronger partnership between these two sectors holds much promise for the future of Illinois agriculture. The emergence of a more efficient and productive total research enterprise will depend on the integrated efforts of academia, government, and industry.

Roscoe L. Pershing, professor and head, Department of Agricultural Engineering, and Arthur J. Siedler, professor and head, Department of Food Science ☐

In Progress

Family life in rural India

How do rural families in a developing country live and work, manage their resources, and deal with the problems of daily life? This was the question that a team of faculty and staff members from the Office of Women in International Development, University of Illinois, attempted to answer through a research project in India. The team, which went to India in 1985 on a Fulbright-Hays grant, was headed by Frances M. Magrabi, professor of consumption economics in the School of Human Resources and Family Studies. As Magrabi pointed out, "We know a great deal about specific problems in developing countries, such as malnutrition, lack of sanitation, fuel shortages, and illiteracy. But we know little about how all these problems interact in a given household and how families — especially the women — attempt to solve them."

In addition to Magrabi, the Illinois team consisted of Barbara A. Yates, professor of comparative education and former director of the Office of Women in International Development; Berenice A. Carroll, associate professor of political science and director of the Office of Women's Studies; Sharon Y. Hart, assistant expanded food and nutrition education state coordinator, Cooperative Extension Service; and two members of the staff from the Office of Women in International Development — Nawaz Bhavnagri, doctoral candidate in early childhood and elementary education, who also served as assistant director of the project; and Ellen Johnson, doctoral candidate in anthropology.

Working with a counterpart team from the Home Science Faculty of

M.S. University of Baroda, the Illinois team collected case studies of families in several villages in Gujarat, India. Team members visited homes, schools, village shops, and rural centers for health and social services; interviewed families; and observed the pattern of daily life in rural households.

The team observed that subsistence farming is the norm in this part of India. Families who own land grow most of their food, process it with simple, traditional tools, and store it in the home. Milk is supplied daily by the family's milk animals — buffalo, cows, and goats. In poorer families, both men and women work in the fields, care for the animals, and do other necessary chores.

A monograph entitled *Household Resources and Their Changing Relationships: Case Studies in Gujarat, India* will be published by the Office of International Agriculture this fall. The monograph will be available for classroom use at the Urbana-Champaign campus, in Baroda, and at other universities both in the United States and abroad. The publication will contribute to an important, emerging area of study at the University of Illinois — that of gender roles in other cultures and the relationship between these roles and international development.

Magrabi says that a set of curriculum guides on this topic, developed through the leadership of the Office of Women in International Development, is already in use on this campus. The guidelines have been distributed to purchasers throughout the United States and in eleven foreign countries.

Village street in Gujarat, India. Most families own dairy animals and grow their own food supply.

Village woman cleaning home-grown grain, which will be taken to the village mill to be ground. She will then use the flour to make rotlas (bread).

University of Illinois at Urbana-Champaign
Agricultural Experiment Station • D. A. Holt, Director
211 Mumford Hall, 1301 West Gregory Drive
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Conference on Illinois agriculture

The University of Illinois will sponsor a conference, "The Future of Illinois Agriculture," from September 8 through 10, 1986. The conference, which is for invited participants, will address the following questions: "How should Illinois agriculture respond to increasing agricultural competition?" "What role should the College of Agriculture play in helping Illinois agriculture meet its competition?" About 160 persons have been invited to participate. They represent farm organizations, farmers, agribusinesses, rural communities, universities and colleges, county, state, and federal government agencies, consumers, and other groups.

The conference will be directed toward strategic planning. Three major sessions will be held, in which participants will (1) specify objectives that need to be accomplished to make Illinois agriculture more competitive; (2) identify strategies to achieve these objectives; and (3) describe the role of the College of Agriculture in implementing the strategies.

A report on the conference will appear in the next issue of *Illinois Research*.

Conference logo designed by Jerry Barrett.

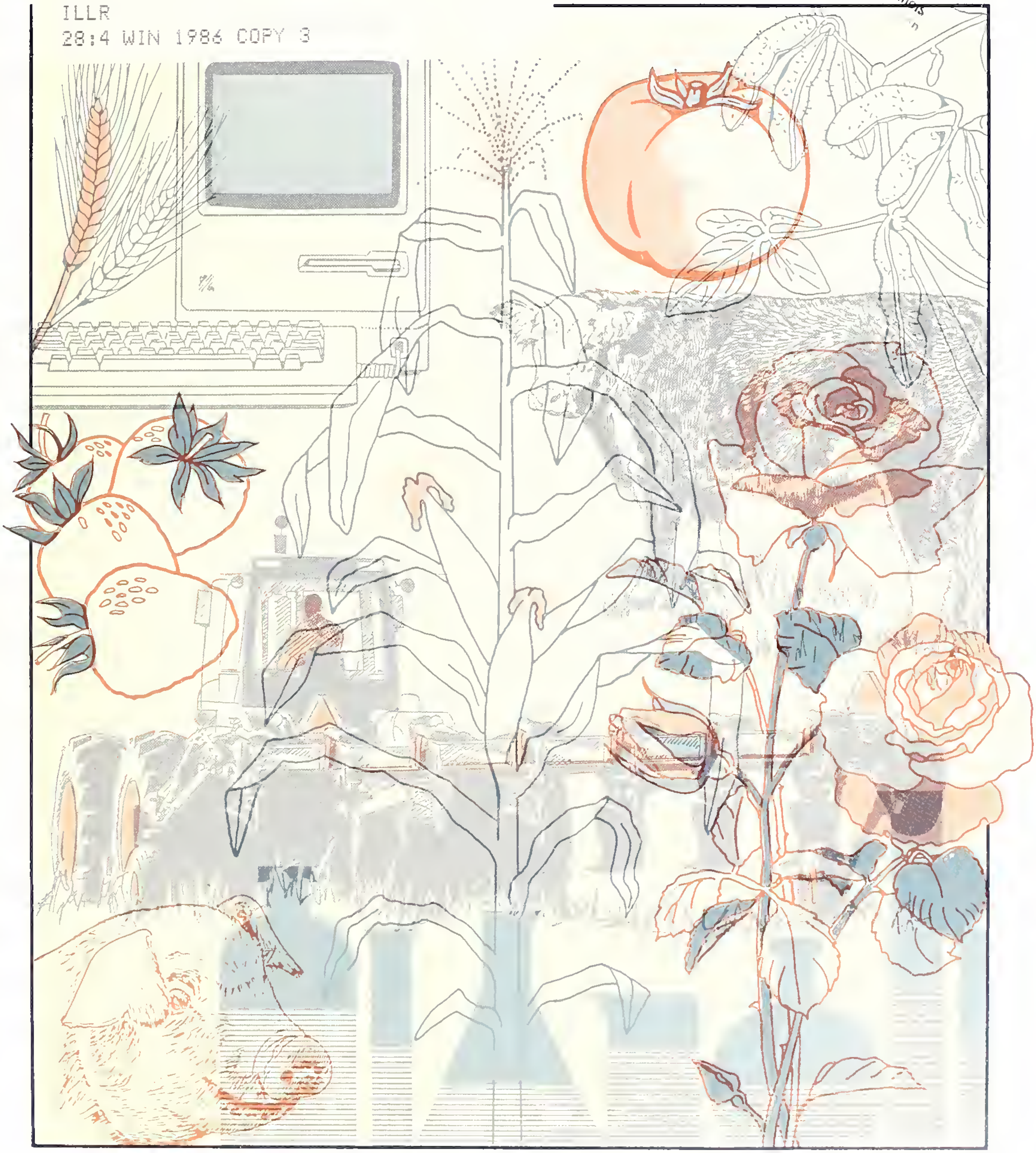
Illinois Research

Winter 1986

The Role of the College of Agriculture

Illinois Research

Agricultural Experiment Station



College of Agriculture, University of Illinois at Urbana-Champaign, Volume 28, Number 4

Renewal time

To the Reader:

Part of the Illinois Research *mailing list is out of date. We are therefore asking certain readers to renew their subscription at this time. If your issue contains a renewal card incorporated in the special wrap-around cover, please return the card promptly. Those who have not received a notice will automatically be kept on the mailing list.*

Future issues will carry in-depth reports on urban plants and animals, the soybean, the human environment, and the marketing of Illinois agricultural products. We will be celebrating the centennial of the Agricultural Experiment Station with a special issue. Brief reports of research in progress will still be included. Our goal is to provide both breadth and depth of coverage so that researchers, teachers, general readers, and special audiences can keep abreast of Experiment Station activities.

Readers have sent many letters of encouragement in the past. To keep us on our toes, we ask you to raise questions and make comments about the information presented in Illinois Research. *Letters that meet the criteria for publication will be printed in this column.*

Zarina M. Hock, editor

Address communications to Editor, Illinois Research, 47 Mumford Hall, 1301 West Gregory Drive, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801

Please limit letters to 250 words.

The Cover

The role of the College of Agriculture in Illinois is profoundly important, especially at a time when agriculture is in a period of transition. For our cover, the artist has created a symbolic picture that brings together the different aspects of Illinois agriculture. Each aspect has been reproduced on a different plane and superimposed on the next one. The total effect is both abstract and concrete — perhaps as is the role of the College in the future of Illinois agriculture.

"At a time unlike any in the past, we must envision the future."

Illinois Research

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Contents

The Role of the College of Agriculture

Forth to the Future

In earlier times, universities provided a sheltered, contemplative environment for a few privileged scholars — a place where these scholars could explore the mysteries of the universe, think great philosophical thoughts, and perfect their artistic skills. About a century ago, the advent of land-grant institutions tremendously broadened the concept of higher education, extending it to common people and practical concerns.

Those of us who work in these unique institutions sense that we are in the midst of another revolutionary change, one that is bringing universities even more directly into the mainstream of the economic activity affecting our nation and the world. The public is becoming aware of the potential of land-grant institutions to be powerful economic resources.

Among other changes, major public and private investments in university research facilities, sizable public and private research grants to university scientists, and high-tech research parks on or near university campuses are strengthening the linkages within the overall research, development, and educational system. These linkages are speeding the development and successful application of useful new technology, thus hastening and increasing the return on society's investment. In addition, research programs that are on the cutting edge add an important dimension to each student's educational experience. Students from institutions that provide such programs are being educated for the future.

The College of Agriculture, primarily because of its Experiment Station and Cooperative Extension Service, has strong traditional ties with farmers and agribusiness people. Never in history have these ties been more important to Illinois than they are now, as Illinois farmers face the challege of competing in a worldwide, capital-intensive, high-technology agriculture. Major initiatives are under way that will make the University of Illinois an ideal setting for the vigorous agricultural research, development, and educational programs described in this issue of *Illinois Research*.

Although our quest for knowledge is not new, the tools at our disposal are changing rapidly. One such tool is the supercomputer. In our two new supercomputer centers that became operative a year ago, exciting work is being carried out. Scientists seek to discover how to apply the best supercomputers of today to solve problems that were too complex to consider just a few years ago and how to design even better supercomputers for tomorrow.

Two other important developments are being initiated on our north campus. These are the Beckman Institute, made possible through the generosity of Arnold and Mabel Beckman, and our Compound Semiconductor Microelectronics Center. The buildings are now being designed, and construction will be starting within the year. Even more important for the programs described here is the biotechnology center being planned for the south campus. This building will bring to fruition the efforts of many people, but especially those of John R. Campbell, dean of the College of Agriculture, and Donald A. Holt, head of the Agricultural Experiment Station, both of whom have received help from many committed supporters in our federal government.

I expect the scientists in our Colleges of Agriculture and Veterinary Medicine to participate fully in the excitement and the new programs now developing. In my 28 years of association with major land-grant institutions, I have never observed such a surge of activity and enthusiasm on any campus as is now evident here.

As readers of *Illinois Research* know, agricultural research today is in the mainstream of scientific inquiry. High-technology agriculture with the greatest impact on human society may fall on the boundaries separating two or more disciplines, or cross several disciplines. To deal with the unprecedented social, legal, and technical problems of a rapidly changing agriculture, scientists will have to draw upon the University's great resources in the basic physical, biological, and chemical sciences; in social sciences; in engineering, medicine, and law. What we learn may improve our understanding of nature, of machines such as tractors or computers, or it may improve our understanding of our fellow human beings — in Illinois or around the world.

The University of Illinois is an exhilarating place in which to work and learn. I am confident that this campus will continue to be a front runner in the expansion of agricultural technology, and I look forward to witnessing the achievements and successes that these new programs will make possible.

Thomas E. Everhart, Chancellor,
University of Illinois at Urbana-Champaign □

The Role of the College of Agriculture

Managing for Global Change

John R. Campbell

Change has long been an integral part of Illinois agriculture and has contributed significantly to our state's economic growth and development. Illinois benefited early on from its rich prairie soils, favorable climatic conditions, and the remarkable ingenuity and hard work of its pioneer families to emerge as a leading force in the U.S. agricultural economy. Following World War II, the introduction of major new agricultural technologies spurred rapid growth in our productive capability and helped create an unprecedented abundance of agricultural commodities and consumer goods.

As domestic markets gradually became saturated, Illinois farmers were able to market their excess agricultural commodities to foreign nations whose own agricultures were more labor-intensive, less productive, and less responsive to growing market demands. Our *economic dependence* on these readily accessible foreign markets grew in direct proportion to Illinois' burgeoning productive capability. It gradually reached the point where nearly half of our total cash receipts from corn and soybeans were generated abroad.

By the early 1980s, Illinois agriculture was experiencing formidable challenges resulting from global changes. The emergence of capital-intensive agricultural systems, protectionist trade and monetary policies, and sophisticated new agricultural technologies among many developed and developing countries had led to a highly competitive situation in the world marketplace. Once-reliable international customers for Illinois food and feed grains now emerged as net exporters of these very same agricultural commodities. As these global socio-economic trends became more and more pervasive, it also became apparent that Illinois agriculture had to adapt to these new conditions in order to survive and prosper.

As we approach the year 2000, what resources and competitive strategies do we now have at our disposal to meet the challenge of global change? Further, how can we effectively manage the current socio-economic conditions to ensure that *change* also is conducive to *economic progress*? Donald A. Holt, director of the Illinois Agricultural Experiment Station, emphasizes that we have four basic resources that will determine our future capability to compete successfully in a global economy — *agricultural technology, human capital, biophysical resources* (land and facilities), and *institutional structure*. In essence, the College's ability to develop, refine, and effectively utilize these key resources in close cooperation with the agricultural community and general populace will help determine the future economic growth and vitality of Illinois agriculture.

Agricultural technology. Coordinated research and development of both *production* and *postharvest*

"Progress is always controversial, because it requires doing something different to move ahead."

— *Winthrop Rockefeller*

technologies are absolutely essential as we strive for least-cost production of readily marketable, high-quality agricultural products and raw commodities. We can demonstrate our reliability to both domestic and foreign consumers by minimizing unit production costs, maximizing product quality, and in many cases developing new "value-added" agricultural products or processes that meet the changing needs of specialized "niche" markets.

Basic, developmental, and applied research programs now planned or ongoing in the College are responding to these complex challenges in meaningful new ways. UI plant scientists, for example, have recently discovered a revolutionary approach to pest control in field and horticultural crops — photodynamic herbicides and insecticides which rely on fundamental biological processes and promise to be economically competitive, environmentally safe, and lethal to many major weed and insect pests.

Ongoing research in crop breeding now emphasizes the incorporation of superior genetic characteristics for disease, pest, and stress resistance, utilizing both traditional breeding methods and advanced genetic engineering techniques. Animal research also is focusing on the use of genetically engineered reproductive hormones, growth regulators, monoclonal antibodies, and other technologies which can enhance both production efficiency and the global marketability of food-animal products.

The emergence of many new agricultural biotechnologies, coupled with the expanding global availability of plant and animal germplasms, means that we now stand at the threshold of even greater breakthroughs in agricultural technology. An historical 1985 agreement signed with the People's Republic of China, for example, paved the way for a cooperative swine genetic research program which will involve both UI animal scientists and Illinois pork producers.

This innovative program is designed to incorporate the most desirable, heritable traits of imported Chinese swine — greater prolificacy and disease resistance — into Illinois swine herds. By becoming "early adopters" of this major new technology, Illinois pork producers stand to realize an estimated $50 to $60 million additional income per year, in terms of increased numbers of weaned pigs per litter and lower fixed production costs.

Today, expanded research in agricultural *product differentiation* at the farm level goes hand-in-hand with applied, "value-added" research in *post-harvest technologies*. These interdisciplinary research efforts can mean the difference between producing surplus agricultural commodities for saturated global markets and providing highly marketable specialty products tailored to a specific consumer demand or market opportunity.

Typically, research is underway in the College to develop new lines of corn containing much higher levels of fermentable carbohydrates. The goal of this work is greater cost-of-product efficiency — generating greater per-bushel yields of ethanol and other valuable organic chemicals and feedstocks, while also reducing overall production costs. Concurrent research efforts with genetically engineered microorganisms and continuous fermentation technologies also are aimed at increasing the efficiency of producing chemical products from grain. Success in these concurrent research ventures would greatly enhance our Illinois corn industry's stature in the global energy market and go far in reducing the growing federal trade deficit.

New research thrusts in the promising areas of value-added agricultural products and related processing technologies are underway, attracting strong interest and cooperative involvements of both well-established companies and fledgling entrepreneurial firms. For example, one type of corn having special starch characteristics shows excellent possibilities for use in the commercial manufacture of biodegradable plastic film and containers.

A new extrusion/expellor process now being developed permits the mechanical extraction of high-quality soybean oil, leaving a soybean meal product suited for human food use. Other ongoing work in extrusion technology is aimed at utilizing Illinois grain in the manufacture of animal feeds, as well as purified and functional protein for use in prepared foods for humans and the pet industry.

A number of low-cost prototype soyfoods and soy-enrichment additives that are currently in the development stage have excellent market potential in the U.S. and abroad. We are exploring viable techniques for harvesting, processing, and preserving high-protein immature soybeans for human consumption. Our meat scientists also are pursuing new processing and packaging procedures for meat products — all designed to meet changing consumer food preferences and lifestyles.

Research in the utilization of food industry co-products, animal wastes,

forest biomass, and crop residues shows considerable promise in the form of many value-added commercial products — high-value chemical feedstocks, animal feeds, fuels, and fertilizers. New or improved bioprocessing techniques are now being developed to make the commercial production of these value-added products more efficient and cost-effective.

Overall, we believe that expanded product-oriented research will eventually help make Illinois farmers more competitive in the world marketplace, create new employment opportunities, and contribute significantly to the state's economy. Commensurate with available resources, the College is aggressively pursuing these goals.

As we rapidly enter the "Information Age," computerized information and management technologies can now place the latest agricultural knowledge at the farmer's or agribusinessperson's fingertips. Participants in a recent College-sponsored strategic planning conference on "The Future of Illinois Agriculture," therefore, favored establishing a statewide computerized information network to link all components of the agricultural community and strengthening the technology transfer system to give a competitive edge to "early adopters." Participants also emphasized the need for "effective management skills training" for decision-makers in all phases of Illinois agriculture.

The administrative leadership in the College is presently developing a comprehensive program — **Operation CROSSROADS** — designed to bring the benefits of computerized management information, decision-aid software, and agricultural expert systems, to agricultural users in Illinois. When implemented, this program would provide individualized management assistance to farmers, agribusinesses, and other users throughout the state and region.

Another regional program, **Project EXTRA,** would utilize a comprehensive package of 150 agricultural expert systems (decision-aid computer software) to help users select and manage farming systems that are both soil-conserving and profitable. Participating agricultural scientists will program software with a problem-solving approach and the combined knowledge, judgment, and professional experience of top specialists in a specific field of expertise. **Project EXTRA** will thus provide a powerful management and decision-making tool tailored to the unique needs of any user.

Human capital. Today, U.S. colleges of agriculture face significant new challenges in the critical area of student recruitment for the agricultural professions. The need to bring the nation's finest scientific talent to bear on the complex problems and opportunities facing our agricultural and food system comes at a time when the pool of highly qualified high-school graduates is dwindling. According to one recent study, the projected population of eighteen-year-olds is expected to decline by 20.5 percent by 1995. Concurrently, the image of agriculture as a promising career field has been questioned because of the industry's recent economic down-cycle and fierce competition from other occupational fields.

As we explore new frontiers in agricultural biotechnology, supercomputer applications, improved nutrition for an aging society, and other equally sophisticated areas of scientific investigation, the need for highly trained individuals pursuing agricultural careers is becoming increasingly acute. A 1986 USDA publication, *Employment Opportunities in the Food and Agricultural Sciences*, projects a nationwide shortfall of more than 4000 qualified agricultural graduates annually through 1990, many in key occupational fields. The human capital shortfall is expected to be the greatest for agricultural scientists, engineers, agribusiness management and financial specialists, marketing representatives, and social service professionals, especially in nutrition and health-related fields.

A high percentage of the human capital shortfall in the years immediately ahead will be among those agricultural graduates having master's or doctoral degrees. Nearly two-thirds of the projected shortage of trained agricultural scientists, engineers, and technical specialists, for example, will be among those individuals needed with advanced degrees — and coming at a time, I might add, when the need for agricultural research and technology transfer has never been greater.

To meet this serious human capital deficit, the UI College of Agriculture is moving aggressively to seek out talented, highly motivated high-school graduates and to support their professional training and development in various agricultural and home economics fields. Our three coordinated scholarship and fellowship programs — the Jonathan Baldwin Turner (JBT) Agricultural Merit Scholarship Program, the JBT Undergraduate Research/Scholarship

Program, and the newly implemented JBT Graduate Fellowship Program — represent key tools in our ongoing effort to attract science-oriented students and to foster academic and professional excellence at all levels.

Graduate education is critically important if we are to ensure the necessary professional and technical expertise for tomorrow's agriculture. The indicated shortfall of individuals having advanced degrees is precisely in those areas where the need is greatest — *agricultural research, finance, management, marketing*, and *social service*.

We believe that the new laboratories and research facilities planned or already constructed on the Urbana-Champaign campus will be a powerful incentive for talented graduate students to pursue advanced studies at the University of Illinois. The many physical and intellectual resources now available here should attract some of the nation's finest agricultural researchers and educators to the service of Illinois agriculture.

Faculty of the University of Illinois College of Agriculture are an essential component of the human capital of Illinois agriculture. Their research, teaching, and extension activities generate and transfer new technology, develop other human capital, and thereby increase the productivity and value of the land, labor, capital, and human assets of Illinois agriculture. No group will play a more important role in Illinois's response to growing agricultural competition than our faculty and staff.

Agricultural scientists, like professionals in other fields, differ greatly in productivity. The differences in productivity mean it is necessary to invest resources to recruit, develop, support, and retain the best. As the number of highly qualified people decreases relative to needs, competition for the very best faculty is becoming more and more intense. In this situation, if state support for agricultural professionals and programs remains static or barely keeps up with inflation, the numbers of faculty and programs must decrease in order to have adequate support for the remaining individuals and their programs. It is virtually impossible to make these drastic reallocations without weakening essential existing programs or failing to keep a broad and diverse mixture of programs. Such considerations will be extremely important as Illinois strives to compete successfully in the global agricultural economy of the future.

Overcoming agriculture's human capital deficit will continue to be a challenging task in the decades ahead. The College has been extremely fortunate to have strong support from the private sector in the critical areas of student recruitment, program enrichment, and scholarship/fellowship funding. We truly appreciate this cooperative involvement in maintaining Illinois agriculture's invaluable human resource base, for human intellect and ingenuity represent the key ingredients for success within a highly competitive global context.

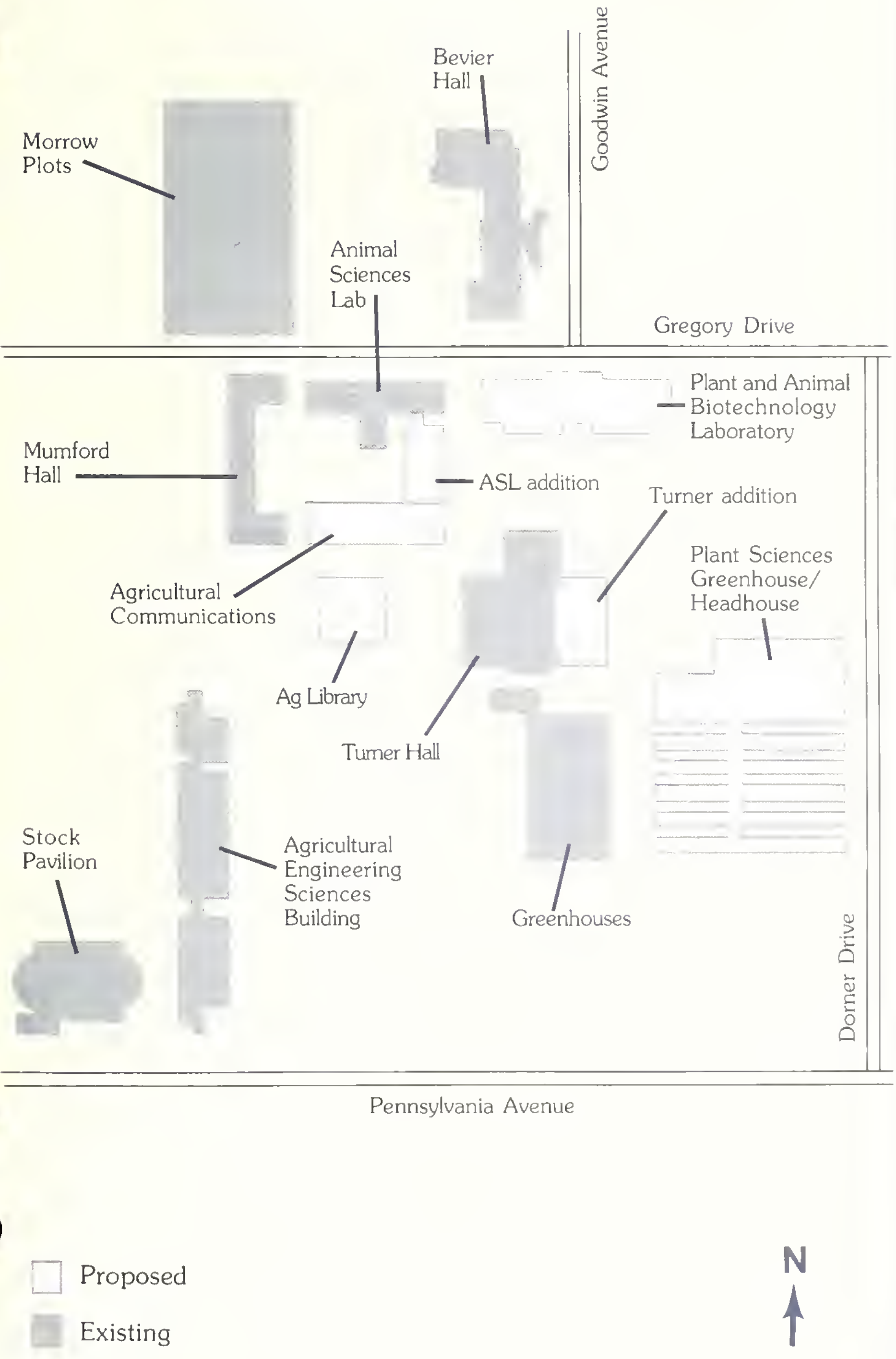
Biophysical resources. Biophysical resources — including our precious cropland base and far-flung capital facilities — represent a critical factor in the competitive formula for Illinois agriculture. Illinois's current position as one of the nation's leading agricultural states has been achieved at considerable cost to the land. A 1985 Illinois Department of Agriculture study indicated that approximately 11.2 million acres of our state's agricultural land (of about 28.7 million total acres on 96,000 Illinois farms) currently exceed acceptable annual soil-loss tolerances of five tons per acre. Illinois now has the dubious distinction of ranking third nationally in acreage experiencing significant sheet and rill erosion, with statewide soil erosion losses now totaling an estimated 200 million tons annually.

Effective stewardship of our irreplaceable land and water resources demands prompt and vigorous action. Alternative land uses such as forage and pasture crops production, as well as forestry, hold considerable promise for stabilizing fragile, highly erodible soils in certain high-risk areas of the state. New College program thrusts having significant implications for soil conservation and diversification of agricultural production include the establishment of a site-specific animal research unit at the Orr Agricultural Research and Demonstration Center in Western Illinois by 1988.

The College also plans to expand its research efforts in forage and pasture crops production/utilization in the Western Illinois region and is working cooperatively with state agricultural officials, alfalfa growers, and entrepreneurial groups to establish new alfalfa-processing and cubing industries in several Illinois counties.

Beginning with the initial Food for Century III projects in the late 1970s, more than $100 million has been allocated recently from state, federal, and private sources to construct state-of-the-art research and educa-

Schematic proposal: College of Agriculture Central Campus



tional facilities for the Colleges of Agriculture and Veterinary Medicine.

This tremendous monetary investment in our physical resources and institutional capability was not merely a chance or fortuitous happening. Rather, it was the product of the considerable public *vision*, *faith*, and *trust* in our capacity to help mold and bring about a brighter future for Illinois agriculture. We are determined that this wise investment will yield substantial dividends in terms of productive research, teaching, extension, and international agriculture programs.

Modern structures such as the Agricultural Engineering Sciences Building, the Plant Sciences Greenhouses/Headhouse complex (under construction), and the planned Animal Sciences Laboratory remodeling and addition will facilitate greatly expanded research in many basic, applied, and developmental areas, including major interdisciplinary and multidisciplinary projects. Our ongoing work in post-harvest technologies, grain quality, and value-added products, for example, involves researchers from several scientific disciplines.

The federally funded Plant and Animal Biotechnology Laboratory, which is scheduled to begin construction in 1988, will afford unique facilities and capabilities for sophisticated biotechnology research — studies in molecular and cellular genetics, recombinant DNA techniques, rapid vegetative plant propagation, monoclonal antibodies, and related scientific areas that will underpin and accelerate our efforts to develop commercially adaptable technologies, products, and processes.

Specialized research facilities such as the Sponsored Research Incubator

Building (also under construction) and the planned Illinois Center for Value-Added Agricultural Research will add significant new dimensions to the College's research capability in applied, product-oriented areas.

The Sponsored Research Incubator Building will house collaborative studies by UI agricultural researchers and fledgling, entrepreneurial firms with prototype, high-tech agricultural products having strong market potential. The present Dairy Manufactures Building will be remodeled and used for applied research on systems to produce new value-added products from Illinois corn and soybeans, including food, feed, fiber, fuel, and chemical feedstocks, as well as to develop new bioprocessing technologies.

Marketing specialists also will conduct marketing feasibility studies, monitor trade-oriented agricultural policies on a global scale, identify potential product buyers, and assess the economic impact of alternative trade policies and marketing techniques on international trade flow. This work will undoubtedly generate a wealth of useful information as Illinois agriculture seeks to penetrate new global markets and develop more diversified crop and livestock enterprises.

A planned Agricultural Library and Information Science Center will incorporate the latest communications, information management, and computer technologies, providing ready access to current agricultural research findings for users throughout the state, nation, and world. The facility also will provide a center for the planned statewide computer network and will utilize computer equipment for information acquisition, storage, retrieval, and dissemination.

Field research and demonstration centers provide an effective means of conducting site-specific and situation-specific research of an applied nature within the various regions of the state. The economic benefits of such research thrusts accrue primarily to Illinois agricultural producers and consumers. Thus, a new animal research unit now under development at the Orr Center in west-central Illinois represents part of a long-range strategy to regenerate our beef and forage industries while promoting soil and water conservation practices.

Applied research in agronomy, horticulture, forestry, and animal sciences conducted at field centers throughout the state continues to emphasize production efficiency and effective cultural practices under a broad range of indigenous conditions — efforts that will pay even greater dividends in the future as we strive for increased crop diversification and differentiation to meet changing global market conditions and opportunities.

Institutional structure. Applications and benefits of agricultural education, research and development, and technology transfer conducted by the UI College of Agriculture reside largely in the public domain and thus become primary components in the broader institutional structure of Illinois agriculture. Land-grant agricultural institutions such as the University of Illinois are unique in their mission and responsibility to conduct research in the broad public interest and to disseminate their research findings, derived technical information, and new technologies to diverse user groups. These include not only producers of agricultural commodities, but also many others who are represented in the complex infrastructure of our food and agricultural system — marketing firms, processors, and distributors of raw or value-added agricultural products; private and governmental organizations who regulate or provide agriculture-related social services, and ultimately all individuals and families who consume these various goods, commodities, and services.

The College's program thrusts in home economics and international agriculture complement — and indeed greatly enrich — our more familiar outreaches toward and interrelationships with Illinois production agriculture. Education, research, and extension in home economics have a positive impact on Illinois citizens in both rural and urban communities, providing much-needed human services in such critical areas as nutrition and health, human development, and consumption economics. Our international agriculture programs contribute to the socio-economic development of emerging nations, while also returning global scientific knowledge, adaptable research materials (such as plant and animal germplasm), and useful technical data on trade and agricultural policy, marketing and consumption trends, and agricultural technology development elsewhere in the world.

Additionally, the College is charged with the education and training of the many technical, managerial, and social service professionals vital to the sustainability and future growth of Illinois agriculture. Through our structured mechanisms for formal and informal education —

resident instruction, extramural courses, and extension adult/continuing education programs — we help prepare the leaders and decision-makers in tomorrow's food and agricultural system.

Because of the exceptional diversity of our agricultural clientele and the broad-ranging nature and importance of our land-grant mission, we believe that additional resources should now be allocated to support essential agricultural research, development, and technology transfer. The College is at this time positioning itself with the necessary scientific talent and physical facilities to forge progressive programs in these critical areas — and thereby help Illinois agriculture regain its competitive edge in a rapidly changing global economy.

While we have been successful in attracting state and federal funds to improve facilities of the College of Agriculture, we are still woefully lacking in operating monies. Illinois ranks twenty-fourth among the states in state funding of agricultural research, forty-eighth in state funding per dollar for cash sales generated at the farm gate, and dead last in state funding per dollar of value-added in agriculture. Applied agricultural research and development, including extension, are critically underfunded. Donald A. Holt, director of the Illinois Agricultural Experiment Station, presents an analysis of this situation in his article entitled "Architects of Change."

The College is currently exploring alternative means of obtaining increased support for applied agricultural research, development, and technology transfer. Participants in the recent strategic-planning conference on "The Future of Illinois Agriculture" strongly endorsed this course of action, while also recommending that research and development expenditures for Illinois agriculture be commensurate with those in other high-performance states and comparable industries. Enlarging the College's institutional capability will likewise accelerate our structured efforts to pursue other high-priority strategies and goals endorsed at that conference — exploring viable new crop and livestock enterprises, strengthening the risk-management and marketing skills of Illinois agricultural decision-makers, and helping commercialize cost-effective technologies and value-added Illinois agricultural products that are attuned to global demands and market needs.

Managing for global change. The monumental changes occurring in global agriculture during the past few years have been viewed by some as a disruption of the status quo, a deviation from normalcy. From a more enlightened perspective, however, such changes may be seen as the catalyst for economic growth and progress. Elsewhere in this issue of *Illinois Research*, the College's associate deans suggest some current problems besetting Illinois and U.S. agriculture, while also outlining the constructive role of the College in an ongoing revitalization process for agriculture.

As the College mobilizes its considerable resources and implements promising risk-management strategies on behalf of Illinois agriculture, its efforts are closely tied to the *concept of change*. Specific examples of this responsiveness and sensitivity to change may be found throughout our major program areas: launching new student recruitment and professional enrichment initiatives designed to alleviate the human capital drain; disseminating new technologies and research-based management information to an increasingly stratified statewide clientele; implementing new scientific linkages, interchanges of technical information, and agricultural development programs on a global scale; and conducting state-of-the-art agricultural research and development programs, with growing emphasis on value-added products and processes.

Thomas Carlyle, the noted nineteenth-century writer and historian, aptly described change as a "painful" — albeit "needful" — process that causes us to exert even higher levels of human intellect and ingenuity. Today, there is a growing need to collectively plan and implement what one recent analyst has called "paradigm shifts" throughout our global food and agricultural system — shifts toward greater efficiency, flexibility, and integration of the entire system, from the producer of agricultural commodities to the consumer of agricultural goods and services.

In the great land-grant tradition of responsiveness to human needs, the UI College of Agriculture is prepared to assume a central role in planning for and managing global change. Our great state certainly cannot afford the alternative, namely, social and economic stagnation.

John R. Campbell, dean,
UIUC College of Agriculture. □

Developing Human Potential for the Agricultural Sciences

William L. George

As we move toward the twenty-first century, it becomes increasingly evident that the most crucial component needed to meet the demands of a global agriculture is the human component. The future of the highly diverse fields that constitute agriculture and related human services will depend more and more on outstanding human resources. During the eighties, land-grant colleges experienced an erosion, both in the quantity and quality of students entering the field. In the nineties and beyond, we must make sure that our colleges are replenished; that we offer the best and most challenging education to the brightest and most talented of students.

At the national level, since 1978, undergraduate enrollments in agriculture and natural resources have declined sharply — by 28.5 percent. As a consequence, only 2.4 percent of the bachelor's degrees conferred in the United States are awarded in the disciplines of agriculture and natural resources. Although enrollments at the University of Illinois College of Agriculture have also declined, the decrease has not been so dramatic because of certain innovative efforts in recruitment. Enrollments have gone down by 9 percent, but at the same time, we have seen an improvement in the caliber of students entering the College.

An image problem. In general, agricultural education and the agricultural sector have a poor image nationwide. As a consequence, agriculture as an academic discipline does not attract a sufficient number of students who will become agricultural experts in the future. In the minds of many, agricultural education means training to become a farmer. Although farming is a very worthwhile profession, colleges of agriculture do not actually train their students to become farmers. This misconception and the current economic problems in the agricultural sector discourage young people from making a career in agriculture.

Our high school vocational agriculture programs, which have in the past produced many outstanding leaders through programs such as Future Farmers of America (FFA), are also facing serious recruiting problems. Unfortunately, the "farming" image is exacerbated by the "vocational" image, which also has negative connotations.

In higher education, we need to create a broad, positive image of agriculture for our youth and indeed for all of society. We can achieve this goal by stressing the scientific components of agricultural education. Our College offers programs in many diverse fields that incorporate the applied aspects of the biological, physical, and social sciences. That knowledge is intended to help solve problems in agricultural and human services.

Recruiting talented students. The College of Agriculture is making a multifaceted effort to (1) attract academically talented undergraduate and graduate students; (2) provide research opportunities for undergraduate students; and (3) offer top-level graduate programs. Such an educational program will lead to professional development at every level. To achieve this goal, we have instituted three programs — all named for Jonathan Baldwin Turner, pioneer Illinois agriculturalist and champion of the land-grant philosophy of higher education during the mid-1800s. The programs are the Jonathan Baldwin Turner (JBT) Agricultural Merit Scholarship Program, established in 1979; the Jonathan Baldwin Turner Undergraduate Research/Scholarship Program, established in 1982; and the Jonathan Baldwin Turner Graduate Fellowship Program, established in 1986. All the programs mentioned above are privately funded. They have been particularly successful in creating excellent opportunities for top students to explore new areas of science and technology, meet major intellectual challenges, and contribute to new scientific knowledge. The programs attempt to retain highly competent students by providing them with competitive financial support and ample opportunity for professional development throughout their college years.

The JBT Agricultural Merit Scholarship Program has provided multiyear merit scholarships for talented freshmen enrolling in the College of Agriculture since 1979. This extremely successful program was initiated with two-year, $1,000 awards that were increased in 1984 to four-year merit awards of $2,500 each.

To date, the College has awarded a total of 469 JBT merit scholarships. Each year, a growing number of highly qualified students is interviewed for this merit award. Last year, approximately 200 students were interviewed for 70 scholarships.

The JBT scholarship program has improved the academic caliber of our entering freshmen. Students qualifying for merit scholarships are in the upper 10 percent of their high school class, either by class rank or by attaining ACT scores of 26 or higher. The total percentage of new students entering the College with ACT scores of 30 or better (that is, those in the top 2 percent) has risen from 3 percent in 1979 to 10 percent at present. The grade-point average of entering freshmen has also gone up.

Not only are we attracting more qualified freshmen, we are also retaining them. The retention rate for students entering the JBT program has been excellent. During the first

four years of the program (1979 to 1982), 91 percent of our JBT scholars graduated from a program in our College or a closely related area, such as veterinary medicine.

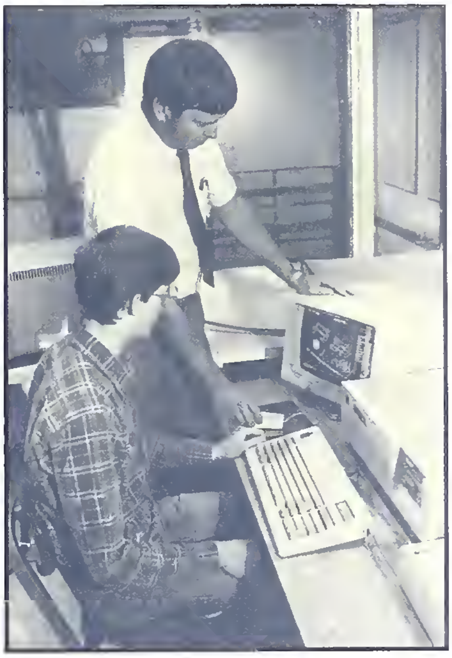
The JBT Undergraduate Research/Scholarship Program was initiated to provide a genuine research experience for juniors and seniors enrolled in the College. The program provides qualified undergraduates with scholarships and financial support for an independent research project, travel expenses to attend scientific meetings to report research results, and funds to help defray costs for publishing their findings in scholarly journals. College faculty members supervise approved research projects, offering the professional guidance normally given to graduate students. Student researchers benefit from the close working relationship with their project advisors and research committees.

The JBT Graduate Fellowship Program was initiated in 1986. Its primary goal is to help recruit and support outstanding graduate students interested in pursuing doctoral programs in our College's graduate departments. Thus it parallels at the graduate level what the other two programs offer at the undergraduate level.

The basic JBT Graduate Fellowship stipend is $10,000 per academic year, with an opportunity to renew the fellowship for up to two additional years. Thus, the total College commitment is $30,000 per selected graduate student. Students are chosen by rigorous criteria for entry into this program. The criteria by which students are retained in the program are equally rigorous.

Because graduate student recruitment in some disciplines is highly competitive, individual departments may offer funds to supplement the JBT scholarship. This important feature enables departments to keep their students rather than lose them to other disciplines.

This new fellowship program has been implemented at a timely moment — when the need for trained researchers and educators is growing. High-quality education is necessary in today's increasingly sophisticated agricultural sciences and in the field of human resources and family studies.



Overall, the College's three JBT programs provide a comprehensive framework for recruitment, support, and academic enrichment that can underpin the student's educational and professional development. The JBT programs are an integral part of the College of Agriculture's long-range efforts to promote academic excellence and to develop human capital for the agricultural, food, and human sciences. We desperately need similar efforts to develop human potential in all the agricultural colleges within the land-grant system.

Agricultural sophistication. The American food and agricultural system is highly efficient and productive. In fact, some argue that our nation's food and agricultural system has become too sophisticated and productive. One may also argue that few career opportunities exist for graduates of Colleges of Agriculture. However, the overwhelming evidence acknowledges that a strongly competitive American agriculture is strategically important to all of our citizens. A food system that will continue to provide high-quality products at low costs to consumers is extremely important not only for the United States but also for world stability.

The applications of science in the agricultural and human sciences offer exciting opportunities in both the short and long run. Biotechnology applications, genetic engineering of plants and animals, computerization, robotics, food engineering, nutrition, and many other science-based activities offer excellent challenges and rewarding opportunities for highly trained young minds.

Striving for excellence. All of us in higher education must continue to strive for excellence in undergraduate and graduate education. Excellence is never an accident but requires hard work. It is achieved by continual insistence on the highest standards of performance. Excellence sets up certain expectations in student and faculty alike. These expectations should be realistically high and fully understood by those involved. Experience has shown that when our expectations are high, students are capable of meeting the challenge. On the other hand, when we expect too little of students, we are seldom disappointed. The commitment to excellence must come from all the constituents that make up the college and university community — the administrators, faculty, undergraduate and graduate students, support staff, and alumni.

Tomorrow's agricultural scientists will undoubtedly be at the forefront of scientific investigation, exploring even more sophisticated means of producing high-quality, economical agricultural products, maximizing the use of our environment and natural resources, and enhancing the individual and collective quality of our daily lives. We clearly have an obligation to train the professionals needed to fulfill these critically important roles. By providing outstanding students with the means to investigate and understand societal problems, we seek to increase their professional competence. We also help prepare them for the ever greater agricultural challenges in the year 2000 and beyond.

William L. George, director,
Resident Instruction ☐

Extension Strategies for the Future

William R. Oschwald

The year 1986 began on an ominous note for the future of the Cooperative Extension Service — not only in Illinois, but also in all other states. The President's budget message included two recommendations that posed serious problems for the Cooperative Extension system. First, the executive budget recommended a cut of approximately 62 percent in federal support for the University of Illinois. Second, the Office of Management and Budget proposed that the language of the Smith-Lever Act — the basic charter of the Cooperative Extension — be modified to limit the scope of Extension work.

The proposed language change would limit federally funded Extension efforts to those linked directly to farm operators. If this language were to become reality, federal dollars could not be used to support projects such as 4-H, home economics, and community development. Even work with farm families that does not relate directly to agriculture and marketing would be prohibited. Because Extension supporters from Illinois and across the country went to bat with Congress, we have won the battle to maintain a viable cooperative Extension system. So, 1986 is now history. What of the future?

The reinstatement of funding and the maintenance of the program's present scope are votes of confidence for Extension. But they carry with them great responsibility. The responsibility of the Cooperative Extension Service is to provide relevant, viable educational programs for the people it serves. These programs are intended to apply research knowledge realistically to issues that directly benefit individuals, families, organizations, and communities. It is research efforts such as these that led to the development of coordinated financial statements. Extension specialists and county advisers have used these statements to help financially stressed farm families.

Our challenge is to *change* even as the world in which we live and work changes. What changes are likely? Response to this question provides the focus of this article.

Issue-oriented programs. The Cooperative Extension Service in the future will need to be more issue-oriented. Programs and priorities should be shaped by the issues affecting our social, economic, and political environments, issues that in the future are going to be more global. Because this is the background against which we must plan our strategies, it is important that we examine the issues more closely.

International economics. The shift in the United States to an international economy will affect the well-being of every individual, farm, and community in Illinois. In fact, the international market will affect the price of corn, soybeans, milk, pork, and beef more than state and national policies do.

Industrial employment, business growth, and community development are already being influenced by international economic forces. The Chrysler-Mitsubishi plant, set up as a result of American-Japanese collaboration, illustrates the point. This joint venture reflects a relatively new approach in international development. In earlier times, Mitsubishi would have had its plant in Japan, and Chrysler in the United States. Had there been collaboration, the site of the industry would certainly have been in the country of the collaborating partner rather than in the United States. The present arrangement, though new to us, benefits both our country and the state of Illinois.

The shift from a national to an international economy should also be reflected in Extension programs. To conduct educational programs that will enhance competitivenss and profitability in Illinois agriculture and revitalize rural communities, we must

Extension advisers must translate research findings into practical advice for Illinois farmers.

increase our knowledge of other countries. We will need to understand their policies, culture, geography, and economies. To ignore international economics is to render Extension programs irrelevant and ineffective. On the other hand, a thorough grasp of international economics will help us develop strategies that will directly benefit the Illinois farmer. Thus, we might adjust the quality of the grain we sell to the demands of the purchaser and increase our exports by meeting the exact specifications of the foreign customer.

The research-Extension relationship. The vital relationship between these two functions will also affect Extension's future. Extension programs require a solid research base. We are fortunate in that the University of Illinois is an outstanding research institution. Its reputation for outstanding research attracts both scholars and financial support, especially in the basic sciences.

The Agricultural Experiment Station, in addition to being strong in basic science, continues to emphasize the importance of relevant applied research. In fact, the Station is moving ahead aggressively to obtain additional support for applied research. Many specialists are on joint re-

search-Extension appointments so that research is efficiently transferred from the laboratory to the farm, agribusiness, family, or community.

In the future, we can expect an even larger number of appointments for campus-based staff that combine the extension and research functions. Area and county staff members will be expected to have a strong research orientation so that they can effectively translate research results and extend them to appropriate target audiences.

The Extension/research linkage will allow farmers and communities to convey their specific needs to researchers. Extension/research ties have always been strong; they will need to be even stronger in the future.

Interpreting policy. Extension programs in the future will be strongly influenced by public policy. Staff members will be called upon to interpret policy. The distinction between the role of advocate and the role of objective educator will require careful and frequent exposition.

As staff members become involved in policy education, they will, of necessity, have to tackle controversial topics. The objective educator must be capable, not only of seeing all sides of an issue, but also of effectively communicating that information to others. Public policy considerations are important, not only in agricultural and economic education, but also in human nutrition, soil conservation, chemical use in plant and animal production, use of renewable natural resources, water use and quality, and consumer economics. Actually, virtually everything that we do in Extension has strong implications for public policy. Take, for example, the use of pesticides. Although pesticides play an important role in crop production, we know that careful and judicious use is necessary to prevent environmental contamination. Agricultural production practice thus becomes closely related to public policy.

Extension Priorities for the Next Decade

1. *Agricultural competitiveness, profitability, and sustainability,* which places emphasis on cost-effective technology and management strategy.
2. *Family well-being,* which focuses on the changing nature and needs of families, whether they be physical, psychological, social, or emotional concerns.
3. *Food, nutrition, and wellness,* which addresses the broad array of issues and concerns of an individual's health and well-being.
4. *Soil conservation and environmental quality,* which relates to the concerns over the effects of agricultural methods and systems on the environment (including problems of erosion, ground water, and surface water contamination).
5. *Community development/rural revitalization,* which places emphasis on economic development in rural areas in direct relation to the social economic well-being of agriculture and agribusiness — thus, the need for the Extension service to provide programs for local governmental officials among others.
6. *Leadership development* of all citizens, but with special emphasis upon youth.
7. *Youth development education,* which focuses on the development of boys and girls of 4-H age into positively motivated young adults.

Setting priorities. We must define the current situation against the background issues discussed above, keeping in mind that our budget has been trimmed. We must set in motion a process whereby we set priorities that reflect the need of each cooperating partner — local, state, and federal. Each partner provides financial support. It is reasonable for us to expect that each partner will expect accountability — in stewardship of resources, development of programs, and the implementation of these programs.

At the local level, the Cooperative Exension Service in Illinois has decided to use a self-study approach involving local staff and volunteers to achieve program priorities. The local level becomes the focal point for the county because this is where the people are. "Ownership" of the Cooperative Extension Service and, for that matter, of the University of Illinois rests with people in local communities.

The self-study approach should help us identify the real issues that affect people's lives — issues that can be solved or positively influenced through Extension education. Local priorities should include those that are (1) unique to the county or local community; (2) relevant to the geographic region in which the county is located; (3) statewide in their implication; (4) a reflection of national issues. The program-planning process allows local priorities to be merged with those of statewide significance. State priorities, in turn, can be effectively utilized in articulating national priorities. We have seen this with regard to the farm financial crisis. Concern for the crisis originated in local communities and worked its way up until it received national attention.

What is the role of state Extension staff, if the starting point of priority setting is at the county (local) level? State specialists should have a broad understanding of their own discipline, the relationship of that discipline to other disciplines, and how interdisciplinary concerns relate to the real world at the local level. The whole issue of conservation tillage is a case in point. The issue has implications for the farmer, the environmentalist, and the agronomist, among others. The concept first originated in the minds of two specialists and a county Extension adviser in Illinois more than twenty years ago. Leaders at the local level succeeded in making conservation tillage a nationally recognized method of erosion control. State specialists should continue to provide leadership, particularly in setting state priorities.

In recent years, Extension has been criticized at the national level

for not paying adequate attention to national priorities. Are national priorities different from state or local priorities? Should they be? If the priority-setting process effectively uses local, state, and national input, national priorities should reflect issues that cut across all states.

The Strategic Planning/Future Priorities Task Force of the Cooperative Extension Service of the University of Illinois began in the fall of 1985 to articulate issues, program priorities, and strategies for the future. The task force developed six program priorities to guide our Extension efforts during the next five to ten years.

The task force requested and received input from county Extension councils, county and area Extension advisers, and departments on campus. The responses were solicited through the "Cold Morning in January" survey. The task force reports that "Six program issues have been identified for major focus in the next five to ten years." (Since then, a seventh priority has been added.) See box on page 13.

Priorities that guide Extension programs in the future will change, just as they have in the past. For example, biotechnology is emerging as a national and state priority, not only in research, but also in Extension. Research in this exciting area will, in the future, need to be interpreted for and extended to appropriate target audiences. The improvement of grain quality is another vital issue — it affects the competitive position of Illinois grain, especially for the export market. Grain quality must receive priority attention in Extension programs.

Soil and water conservation are also important considerations. Certain goals were mandated by the Food Security Act of 1985 and by "T by 2000" for Illinois. (The latter was a state project that defined the level of the soil's tolerance [T] to erosion and set up a goal to reduce that erosion to a clearly defined, acceptable level by the year 2000.) Although this priority is closely related to environmental quality, it has particular implications for Extension programs, and as such, can appropriately be regarded as a separate item, highly deserving of effective attention by the Cooperative Extension Service in Illinois.

Target audiences. Program priorities are little more than paper targets unless they relate to the people we serve and to their needs. In the future, Extension must target programs to specific audiences, rather than to broad, general groups of people. Audiences targeted by Extension are (1) farmers and landowners; (2) families and individuals; (3) youth; (4) communities. These categories are in turn broken down into very specific subgroups. Thus, for example, in the category of farmers and landowners, two groups that are identified are full-time commercial farmers and owners of small farms. In the category of families and individuals, financially stressed farm families require priority attention. Families, whether rural, suburban, or urban, range from traditional to single parent. Youth may be defined as rural or urban or according to age group. Similarly, all categories are broken down very finely into all possible constituents.

The list of target audiences is not definitive, but it helps us select and shape our priorities. We must continue to tailor the educational message to fit the needs of specific audiences to the greatest possible extent.

Extension staff. As members of the Extension system, we must understand the environment of the people whom we serve. Staff members are expected to set relevant priorities, and plan, conduct, and evaluate programs. As mentioned earlier, these programs will be targeted to specific audiences. To accomplish this charge, and to accommodate change, staff members at county, area, and state levels will need to be flexible. They must be able to gear up in order to effectively deal with emerging issues and problems, carry out effective educational strategies, wind down when the program needs are satisfied or no longer exist, and then start on new issues, problems, and concerns. In order to use scarce resources effectively, we will need to cooperate with other providers of educational services. We need to aggressively seek out opportunities to cooperate with community colleges, local school districts, local public and private agencies, and other institutions of higher education in Illinois. We must also collaborate with private sector business firms, local governments, and other relevant organizations. Cooperative Extension staff members will have unique opportunites to exercise leadership in this context. And such leadership is consistent with our function as Extension educators. Moreover, leadership will require that we function not only as individuals, but also as members of an interprogram area, or of an interdepartmental or interdisciplinary team.

Our strengths. Coping with an uncertain future to accomplish what appear to be uncertain goals requires strength. Our strengths include staunch local and state support from the people we serve. We work with dedicated, committed, and supportive farmers, families, volunteer leaders, 4-H club members, commodity groups, and other private organizations, as well as with cooperators in other local, state, and federal public agencies.

We have a competent staff of professionals, paraprofessionals, secretarial, and other support staff. We have a strong research base in most areas of agriculture and home economics, a base that will be even stronger in the future. As a Cooperative Extension Service and as a College of Agriculture, we have the capacity to respond and help people use the fruits of research in improving the quality of their individual and collective lives. These strengths are essential ingredients in the formula that generates relevant and effective programs. The future is bright with opportunities for the College of Agriculture here at the University of Illinois, including the Cooperative Extension Service.

William R. Oschwald, director, Cooperative Extension Service ☐

The Global Picture

Dennis T. Avery

Agriculture today is vastly different from what it was twenty years ago. The world's agricultural potential is rising rapidly. In the decade from 1974 to 1984, world farm output rose at 2.7 percent annually — significantly faster than the pre-1970 rate of 2.5 percent. In fact, farmers in developing countries raised their output at 3.8 percent per year, and in the 1980s boosted that rate to 4.8 percent! Farmers in the affluent countries raised their output only 1.5 percent annually — and even at that rate produced surpluses.

At least 25 countries now consistently produce surpluses, including Finland, Saudi Arabia, and Indonesia. The annual world surplus amounts to more than 150 million tons of grain *per year* — or at least 50 percent of the annual grain trade. More than half of the surplus-producing countries subsidize their extra commodities into the world market.

All over the world, scientific research in agriculture has brought about great advances, which have increased production. Advances such as those listed below are certain to continue in the years ahead.

- Three years ago U.S. wheat growers planted the first practicable hybrids, with yield increases of 25 percent. This year, France offered its first hybrid wheat. The rest of the world's wheat breeders are undoubtedly hot on the trail, and most of the world's wheat crops will probably be hybridized over the next decade or so. The yield gains could be as big as they have been in corn.

- Short-season corn varieties have moved the border of the Corn Belt 250 miles north in the last decade — into central Canada. East Germany is planting corn for the first time, to displace corn imports with corn/cob silage. The Soviet Union is moving corn north, and Argentina wants to move it south.

- Turkey is building three big dams in the upper Euphrates valley that will irrigate as much cropland as we plant in Nebraska.

- New white corn varieties are doubling yields in West Africa and Central America.

- A whole family of hybrid sorghums promises doubled and tripled yields and greater drought resistance for much of Africa.

- A new farming system can grow crops on millions of acres of black, sticky Verisol soils in India and Sudan.

- China has bred a new shorter-season soybean for Manchuria.

A farming "success model" has emerged in the world, featuring farm research, price incentives for relatively small farms, and efficient off-farm support systems to provide inputs such as fertilizer and pesticides. China scrapped its big communal farms in 1979, leased the land back to families and small work groups, and got a 50 percent increase in farm output over the next six years.

Farm price subsidies and trade barriers will probably continue to encourage additional farm production in most of West Europe and Japan for at least the rest of the 1980s, despite lower U.S. export prices and strong trade reform pressures.

Continued agricultural research in the United States is crucial if we are to stay competitive in world agriculture. This research will boost our own farm efficiency and expand the range of farm products. The profitability of U.S. agriculture, therefore, will be determined in a global context.

Dennis T. Avery, senior agricultural analyst, Bureau of Intelligence, U.S. Department of State ☐

International Agriculture: Mutual Aid

John J. Nicholaides III

Recently in the Department of Agronomy, faculty members Theodore Hymowitz and Richard Bernard used germplasm to develop three soybean lines that are free of the trypsin inhibitor. The presence of this inhibitor affects the action of a digestive enzyme, trypsin, reducing the digestibility of soybeans. Normally, the soybeans must be heated to deactivate the inhibitor. Now, as a result of the development, soybeans may eventually be fed directly to swine and poultry without having to be heated. According to one estimate, U.S. producers will save between $100 million and $500 million annually if they use varieties to be developed from these soybean lines. This achievement was the direct result of an international exchange. The germplasm came from Korea and was placed the U.S. Department of Agriculture soybean germplasm collection, which is maintained at the University of Illinois at Urbana-Champaign. This benefit demonstrates the importance of international agriculture to Illinois and the United States.

Indeed, the Office of International Agriculture (OIA) adds a global perspective to the teaching, research, and public service functions of the College of Agriculture. The programs of the OIA also make positive contributions to those efforts of the United States directed toward humanitarian acts and national security. As agriculture improves in a developing country, so does that country's economic well-being and political stability, as well as its imports of U.S. agricultural products.

The great demand by U.S. agribusiness for agricultural students who appreciate and study other cultures and languages again illustrates the importance of international agriculture. Faculty and students involved in agricultural programs overseas can provide insights that will improve the competitiveness of our agribusiness industry in the world market. Serving our clientele within this state, therefore, means helping them to participate more fully in the global agricultural economy. We cannot, indeed, must not, draw back from our international responsibility.

The Office of International Agriculture. Established in 1967 as one of the first in the United States, the OIA is directed by an associate dean of the College with the dean's support. The OIA is involved in five major programs concerned with international development in agriculture. The Office has initiated three important institution-building projects — in Zambia, Pakistan, and Kenya. Two other projects have a worldwide scope — the International Soybean Program (INTSOY) and the International Program for Agricultural Knowledge Systems (INTERPAKS). INTSOY seeks to improve human nutrition through use of the soybean, and INTERPAKS seeks to improve the technology transfer system.

I will discuss only INTSOY, primarily because its research could be of more immediate though not necessarily greater benefit to Illinois than the others. INTSOY is creating new value-added products from the soybean for use in both the lesser developed countries (LDCs) and developed countries. One such product is the immature, green soybean, which when used as a vegetable has twice as much protein as any other vegetable. In my opinion, it is the most delicious of any bean or pea.

A soybean-corn snack has also been developed, which is similar to the potato chip, but with 17 to 20 percent protein. As a snack food, this chip has great potential. Another product is soy milk, developed by means of a low-cost process, suitable for those who do not have the lactase to digest cow's milk and for those in developing countries who cannot afford milk. There are many other soybean products, including soy ice cream and soy yogurt. The University of Illinois is developing technologies to produce these and other soybean products. Farmers and producers in the state are therefore getting the opportunity to adopt the new technology early. They thus stand to benefit most from these developments.

Enlightened self-interest. Former UIUC Chancellor John Cribbet stated in a major address that "the truly great universities of the twenty-first century will be international." Just as true is the statement that "the truly great economies of the twenty-first century will be global." Both these statements motivate us at the University of Illinois to be involved in international agricultural development. Purely and simply, this involvement serves our own best self-interest.

The paradox. How, one might ask, can anyone promote international development when one has seen U.S. farmers cope with unprecedented production surpluses and major declines in export sales? Exports are down to an estimated $26 billion from nearly $44 billion in 1981.

At the same time, people in many countries of the developing world are experiencing severe food shortages. Why don't we just sell them some of our food surpluses, one might ask? Perfect — if these countries had the money to purchase the surpluses. But they do not; nor do they have the knowledge to produce sufficient food for themselves. Both problems — those of hunger and poverty in the LDCs and the decline in U.S. agriculture can be resolved through the same means: international agricultural development. The latter is, in fact, better described as *mutual aid*.

Economic benefits to the United States. Often, the economic problems of the agricultural sector in the United States are blamed on agricultural development work in LDCs. Those who hold this view argue that by helping developing countries grow food, we cut off a market for U.S. farmers. Much evidence can be cited, however, to

counter this argument. International agricultural development in which U.S. universities participate has not caused the problems faced by our farmers. In fact, to stop international agricultural development would be to decrease U.S. agricultural exports.

LDCs, our fastest growing market. In the lesser developed countries, the demand for U.S. agricultural products depends on economic prosperity. Agriculture constitutes the largest sector in the economies of most developing countries. When domestic agricultural production improves, it stimulates development in nonagricultural sectors and increases the availability of foreign exchange. As people's incomes increase, so do the demands for meat and value-added products, many of which will be purchased from the United States, provided the price and quality are right. In other words, food exports to LDCs are directly related to the ability of these countries to pay. Poor people and poor countries do not buy food or much of anything else.

LDCs have the fastest population growth rate in the world. Each day, 224,000 more people are added to the face of the earth, that is, roughly twice the population of Champaign-Urbana. In less than three years that number equals the population of the United States. Fully 90 percent of this increased population by the year 2000 will be in less developed countries. To purchase food for their growing populations, these countries will have to have a solid economic base.

Developing countries, then, are our fastest growing market. In 1976, LDCs purchased 30 percent of our agricultural exports; by 1985, their share grew to 51 percent. USDA's Foreign Agricultural Service projects that this trend will continue.

Brazil: an example. It is often argued that when developing countries increase production, they reduce their imports. Brazil is often cited as an example of a developing country whose increased agricultural production has negatively affected U.S. agricultural exports. In fact, Brazil's agricultural production increased 66 percent from the period 1970-1972 to 1983-1985. This expansion was one of the fastest in the world. It was accompanied by a rapid growth in the quantity of U.S. agricultural products purchased by Brazil. From the 1970-72 period to 1983-85, Brazilian imports of U.S. food products increased from $77 million to $465 million. During this period, the proportion of U.S. commercial agricultural sales (versus U.S. government-supported export sales) increased from 36 percent to 99 percent. This is precisely the kind of increase that our farmers need and like to see. During the same period, the dollar value of U.S. exports to Brazil of soybeans, wheat, corn, and products from all three increased radically (Fig. 1).

At the other end of the scale, from 1970 to 1985, per capita agricultural production in Sierra Leone actually declined by 11 percent, whereas total agricultural production increased only 21 percent, about one-third of Brazil's increase. A perfect candidate for increased sales of U.S. agricultural exports, you might say. Look at the data as expressed in Figure 2. Commercial sales to Sierra Leone decreased sharply from 1970 to 1985. Certainly, this is not a situation that our farmers want to see.

Brazil and Sierra Leone reflect accurately the possibilities for U.S. agricultural exports to countries at both ends of the development scale. John R. Campbell, dean of UIUC's College of Agriculture, in testimony before the U.S. House Agriculture Committee in October 1983, stated that the faster the growth in agricultural production in developing countries, the greater the increase in their agricultural imports.

Specifically, during the 1970s and early 1980s, ten developing countries with fast rates of growth in agricultural production increased their food imports by an average of 68 percent, whereas ten developing countries with slow agricultural production growth rates increased food imports by only 3 percent. In developing countries, changes in per capita domestic agricultural production are positively correlated with per

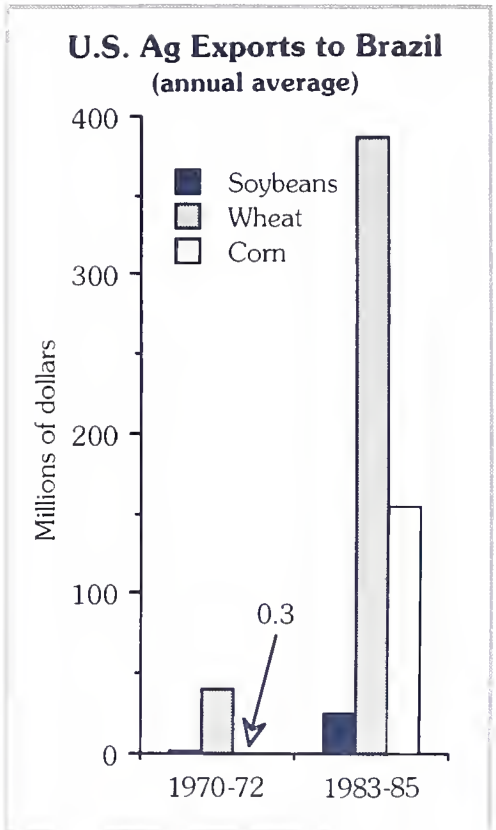


Fig. 1. As Brazil's agricultural production has increased, so have its imports of U.S. (commercial) agricultural products. The data suggest that developing countries import more products when economic conditions in those countries improve.

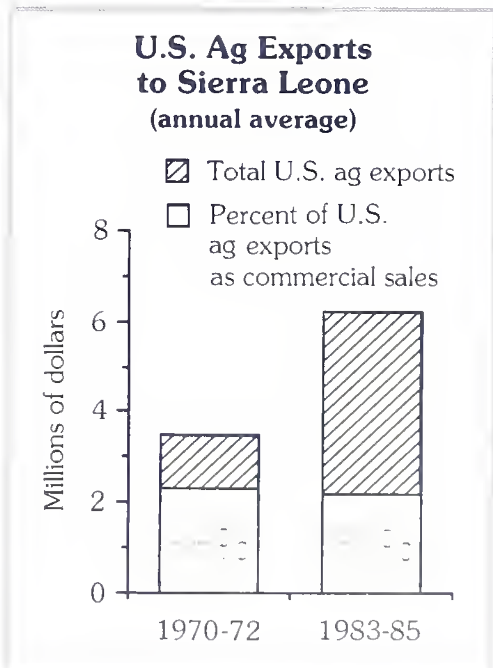


Fig. 2. Sierra Leone's agricultural production has declined, and so have commercial sales of U.S. agricultural products to Sierra Leone.

Green soybeans, frozen and packaged. Eventually, this product will be commercially available to consumers. Green soybeans are highly nutritious, containing twice as much protein as green peas or lima beans.

capita imports of agricultural products.

Today, there are seven former aid-recipient countries, each of which imports annually more than $1 billion in agricultural products from the United States. South Korea for example, imported an annual average of $1.623 billion worth of U.S. agricultural products during 1983-85. We should be willing to give the chance to as many countries as possible to import a billion dollars of U.S. agricultural products. That's one reason we're involved.

Other reasons for involvement. There are, of course, other important reasons why we are involved in international agricultural development:

• *Germplasm access.* Our involvement in international agricultural development makes available formerly inaccessible crop and animal germplasm. Germplasm from other countries has played an important role in U.S. agriculture. None of our major commercial crops is indigenous to the United States, and none of our breeds of livestock, except for some crosses, originated here.

Access to new germplasm can help us improve our cultivars and breeds. For example, in 1970, the northern corn leaf blight devastated U.S. corn producers, causing a 15 percent yield reduction. The gene in our new corn cultivars, which are now resistant to the blight, was obtained from Latin American maize lines. The gene would have been unavailable without our international germplasm exchange. I have already referred, in my introductory remarks, to the germplasm exchange that resulted in soybean lines free of the trypsin inhibitor.

Because they recognized the enormous potential for improving crop and animal breeds, Dean John Campbell and Illinois Governor James Thompson worked hard for the soybean, maize, and swine exchange agreement with the government of China. This agreement, which was signed in March 1985, has the potential to provide many benefits to Illinois and U.S. agriculture.

• *World peace and stability.* International agricultural development increases world peace and stability. There is, in my opinion, no clearer formula for social and political turmoil than poverty and hunger in the LDCs. We will see governments change in many of these countries as a result of poverty and hunger. Some changes will come from the ballot box; others through less peaceful means. Only when people can feed their families and have a chance for a better life will we see more stability in LDCs and the world as a whole.

• *Humanitarian concern.* The final and, perhaps, most important reason for international agricultural development, is our humanitarian concern. We are all human beings and, as such, brothers and sisters to each other. Who among us cannot help but be touched by the horrible plight of the starving people, regardless of the form of government under which they live? The long-term solution to the predicament of those people is to help them learn how to produce some of their food and earn enough to purchase the rest. Hopefully, if they know us as friends and if our prices are competitive, those purchases will be from us. The security afforded by a life without poverty and hunger is the basis for a life of hope and dignity.

• *Commitment to international agriculture.* Willard Severns, an Illinois farmer and incoming chairman of the OIA Advisory Committee, has emphasized the benefit to the United States from international development: "The price of retreating from world markets is too high. World agriculture, like the computer field and other areas, is a high-tech battlefield.

"We must make a commitment that we are a part of the world agricultural system. The future of farming in Illinois is tied to international agriculture and we cannot turn back the clock. Some view this as a threat. I think of it as a new challenge that I know we can meet."

According to Clifton R. Wharton, Jr., Chancellor of the State University of New York, "for affluent nations such as the United States, providing development assistance remains one of the moral imperatives of the age. Indeed, the overwhelming evidence is that we benefit economically from foreign development." These sentiments succinctly express our reasons for international development.

The University of Illinois has made a commitment through the College of Agriculture's Office of International Agriculture and its programs. This commitment and consequent actions by OIA will ensure that Illinois farmers and agribusinesses benefit from new technologies and improved economies as they enter the twenty-first century. There could be no better mutual aid.

John J. Nicholaides III, director, International Agriculture ☐

A Strategy to Compete

Kenneth W. Gorden

The market for agricultural production has changed. Once we were the only supermarket in town, but now there are several others. What shall we do? Should we condemn these others for invading our domain? Berate our customers for shopping around? Shall we withdraw and become a neighborhood grocer — or close our doors now? Or, can we compete?

Illinois farmers have several advantages that would give them a competitive edge in the world market. The expanse of our fertile soils is well known. Rainfall and temperature are generally conducive to the reliable production of raw materials for food and fiber. Our farmers are astute, innovative, and aggressive. They are served by agribusinesses that efficiently provide equipment, repairs, and supplies.

Over time, the development and flow of new crop varieties, equipment, and production practices have continued unabated. Information by the media, advertising, and Extension is disseminated through a system unequaled anywhere. The infrastructure of the marketing chain is capable of expeditiously handling agricultural production.

Clearly, we have the resources. What we lack is a desire and a strategy to compete. We have not yet decided to be an exporting nation. We have not focused on what we must do to "produce for the market" — and do it at a profit. To do so, we must consider the following strategies:

- Moving products at world prices — there is one market, the world.
- Making market development a high priority. If we create and build new markets, we establish new and reliable customers.
- Developing quality products and attentive service in order to keep satisfied customers.
- Processing our raw agricultural products into food and articles that meet the specific needs of foreign customers. This development can enhance the income of farmers and manufacturers.
- Using innovative methods to sell products in many countries short of cash.
- Reducing costs and improving efficiency. These are fundamental to any successful farming enterprise.

The University of Illinois College of Agriculture can play an important part in the decisions and strategies that will make agriculture competitive because information and education are crucial. As in other crisis situations, many proposals will appear for alleviating indebtedness, risk, low prices, rural social upheaval, foreign competition, and other problems. Before acting, farmers, farm leaders, and the public must understand the pros and cons of the issues. Only then will they be able to take constructive action to improve the current export situation. A prime service of the College is to present the issues forthrightly and courageously.

The College is the research arm of Illinois agriculture. We cannot turn off the enquiring nature of human beings. Nor can we stop change, which continues relentlessly. We are all aware of the dramatic changes that have occurred in agriculture since the turn of the century, when we began earnestly pursuing research and disseminating it to farmers and agribusinesses. Should research have been discontinued at some point in the last century? Hardly! Although the research on new products or on new uses for farm products warrants immediate attention, research to improve production efficiency must also continue and accelerate.

Agriculture is changing and will change more dramatically in the future. Change can be imposed upon us or it can be engineered by us. Agricultural leaders must comprehend the changes and manipulate them for the long-term benefit of agriculture.

Many of the problems of agriculture are of our own making. We have tried to curtail production and at the same time have high guaranteed prices that encourage more production. We have tried to increase demand, but have not been successful because high prices have throttled usage. Price guarantees generate production; high prices discourage sales. Embargoes have alienated foreign buyers, causing them to search for new suppliers. High wages and low productivity in industry have reduced the competitive position of U.S. farmers by increasing their cost of supplies and services. We must turn back to the basics of research, marketing efficiency, and our pursuit of the competitive edge. We will thus be able to meet the threat of foreign suppliers. We have the resources to be an export nation. And we can compete. We must recognize our status as an exporter and implement a "strategy to compete." Not to compete is to withdraw, to stagnate, to decline.

Kenneth W. Gorden, farmer and member of the College of Agriculture Advisory Committee □

Victims of Change

Donald A. Holt

One morning in the spring of 1946, I climbed in the old '37 Buick with my dad, and we drove across the road to pick up Uncle Ted. He wanted to survey the damage done by the heavy rains of the previous two days. Uncle Ted, my grandfather's brother, lived alone in the original Holt farmstead. He was a tough, wiry little man with an iron will. In the weeks prior to that morning, we noticed that he wasn't quite himself, often seeming depressed.

We drove back through the barnyard and an empty feedlot, past the huge barn we always called the "sheep barn," even though it hadn't housed any sheep for thirty years. A short drive down the grassed lane that ran west from the buildings brought us to a gravel road that bordered the lower 120-acre tract of the farm. We got out of the car and walked along the headland.

The situation was bad. In places, an inch or two of silt, washed from the fields above, covered the gravel road. A torrent of muddy water flowing down the long western slope of the Minooka Ridge had carved an ugly gash in the uniform blackness of the unprotected field below the road. The water had cut down through the dark topsoil, exposing the brown clay beneath. Close to where we stood, it had penetrated deep into the bluish-gray glacial till that had lain there undisturbed for tens of thousands of years.

I will never forget the look on my uncle's face, that look of torment, anguish, and helplessness. It was not a new sight for him. He had lamented for years that the gullies kept getting deeper and more difficult to cross with equipment, even though they were plowed in every year. He knew there were ways to correct the situation, but was absolutely convinced that a farmer couldn't afford to use those soil conservation practices. In that area, soil conservation inevitably meant raising livestock to utilize the necessary cover crops. This incurred more financial risk and brought on many other problems, including weeds. He was death on weeds.

That morning, Uncle Ted stood transfixed by that ugly scar on the landscape, impaled on the horns of the dilemma. This was the land he loved, so much so that he never spent a night away from it in the 63 years of his life. The full realization of what had happened, not just that spring, but over many years, seemed to come down upon him, crushing

Architects of Change

Donald A. Holt

Agriculture today functions in a global context. To meet rapidly growing international agricultural competition and to operate effectively in an increasingly volatile international economy, Illinois agriculture must change in substantial and unprecedented ways.

Who stands to win or lose? We must recognize the fact that the stakes are very high: farmers are not the only ones who will lose out if we do not face the current situation squarely. The jobs of over one million Illinois citizens and the support for their families depend directly on the success of our agriculture. People employed in supplying agricultural inputs and finance and those in the processing, marketing, and distribution of farm products depend for their income on the volume of our agricultural business. Since that business, in turn, involves substantial exports, we simply cannot afford to lose our share of global agricultural markets.

In the final analysis, despite the complexities induced by embargoes, unfair trade practices, agricultural subsidies, and other governmental interventions, the state or nation that can produce and market the most useful, most competitively priced agricultural products of the highest quality will capture a sizable share of an enormous, expanding world market. Such an economy will thrive. For Illinois, one of the top four agricultural states in the nation and the one with the greatest natural potential for agricultural productivity, the other alternative is unthinkable.

Effectively managing research and development. Our success in meeting the challenges and taking advantage of the opportunities facing Illinois agriculture will depend in large measure on the effectiveness with which we manage the research and development (R&D) system that serves that great enterprise. The agricultural R&D system in Illinois was adequate as long as the United States faced little competition from the subsistence agriculture that characterized much of the rest of the world. Internal competition existed among U.S. farmers for ever-expanding domestic and international markets, but the U.S. public benefited no matter who won that competition.

Now, technological developments are changing world agriculture. As other countries develop productive, capital-intensive agriculture, we will have to improve our system substantially to meet the competition. Progress made by our competitors is shown in Table 1, page 22.

If we examine the Illinois R&D system from the standpoint of the needs and interests of the people of Illinois, we will observe that the system has one, serious flaw. Unlike the other big agricultural states, Illinois lacks a recurring line item in the state budget for agricultural research

his spirit. At that moment he uttered the sentence that he would repeat many times in the two years before his death: "Everything's going to hell."

This family of Holts came from England in the 1850s. They had been cotton and woolen millers in the midst of the European industrial revolution. The great depression of the 1840s eventually brought them to northeastern Illinois where they established a farm that was almost a mile square — big in those days.

Their industrial background was evident. They mechanized everything. The corn cribs and shops had line shafts driven by small steam engines and early gasoline engines. Grain elevators, grinders, saws, machine tools, and other pieces of equipment were powered in this manner long before many other farmers had adopted these labor-saving approaches.

They were superb mechanics, maintaining equipment in good working order, sometimes for years after the equipment was obsolete. For many years, they owned and operated the only big threshing machine, corn sheller, ensilage cutter, and clover huller in the area.

My grandfather ranged as far as 25 miles from home, doing custom work for neighbors. That was a long way to ride a steam engine or drive a team of horses.

The system worked well at first, when the fields were small and there were lots of animals. But as they mechanized, they tore out fences to make the fields larger. If it meant less turning, they plowed, disked, planted, and cultivated up and down the slopes. They implemented a corn and oats rotation that lasted on some fields for 50 years.

If you will pardon some personal bias, they were also good people — honest, hard-working, family-oriented, generous, and cooperative. They didn't "deserve" what happened. But Mother Nature can be very unforgiving. As the saying goes, "It rains on the just and the unjust alike."

The fields eroded. The gullies became so deep they couldn't be crossed. The yield levels dropped to 20 or 30 bushels of corn in a good year. The changes were occurring, but, for one reason or another, the family couldn't deal with them. It was the classic problem of American agriculture, perhaps of human life. How do we perceive the need for change? How do we adapt to change? How do we, in fact, take advantage of changing conditions?

Donald A. Holt, director, Agricultural Experiment Station ☐

and development. No recurring state general revenue funds are earmarked specifically for agricultural research. Recurring state support for this activity now funnels through the Illinois system of higher education.

Some agricultural R&D activities, including basic and early-stage developmental research, have goals that are compatible with and complement those of higher education. Others, particularly the site-specific and situation-specific research conducted on research farms throughout the state as well as related extension activities, play a different role.

By conducting these activities, the Illinois Agricultural Experiment Station, the Illinois Cooperative Extension Service, and other state agricultural institutions serve as the principal R&D arm of a production industry, namely production agriculture. Because these activities do not involve large numbers of undergraduate or graduate students and are not campus-based instructional programs, they do not and should not compete well for the resources allocated to higher education.

As a result of this weakness in the institutional structure of Illinois, the state's investment in agricultural research and development is relatively small. Among the states, Illinois ranks forty-eighth in recurring dollars invested in research per dollar of cash sales in agriculture, and dead last in recurring dollars per dollar of value added in agriculture. Whereas private industry invests an average of 2 percent of cash sales in research and development, the R&D program directly supporting production agriculture in Illinois is funded at less than 0.3 percent of cash sales.

How the agricultural R&D system works. Basic research generates many ideas for new agricultural products (Fig. 1). Once potential input products such as fertilizers, feeds, pesticides, and animal pharmaceuticals are identified, the private sector will usually conduct the necessary applied research to make these products marketable. The private sector's investment in this part of the system is greater than the investment in all the rest of the system combined.

Most of the agricultural input products come from large, foreign-owned or multinational, private firms that are now developing, manufacturing, and marketing these products all over the world. Our competitors, many of whom are less restricted by environmental concerns than we are, may have even better access to these inputs than our own farmers. Effective new pesticides, for example, are sometimes available in other countries before they are approved for use in the United States.

After private research generates marketable products, public research institutions ordinarily come back into the process to test and compare the products. They must also identify, through systems research, ways to integrate these products into safe, workable, and profitable production or utilization systems. After the systems research has been completed, technology must be transferred to the user. This occurs either directly or indirectly via extension and the instructional programs offered by public institutions.

Finally, the user must undergo a period of learning and practical experience with the product in order to use it effectively. Trial and error is costly and inefficient. A good R&D system spares the user much of this expense by undertaking the trial and error phase in the development of a particular technology or product.

A similar sequence of events occurs with management-oriented research, that is, research that does not involve products. The difference is that public institutions are actively involved through the entire process (Fig. 1), because this research usually results in public information rather than salable, proprietary products.

Linkages are essential to the success of the R&D system. Information flows both ways. Ideas for improving technology are generated by basic research and must move toward application. In turn, users of the technology provide useful feedback that triggers new basic, applied, and systems research to improve technology further.

In a highly competitive industry, technology is a two-edged sword. Once a new and useful agricultural technology has been developed for commercial application, those who adopt this technology early are the first to benefit (Fig. 2). After most producers have adopted the technology, supplies of the resulting agricultural products increase, prices come down, and consumers become the beneficiaries of the research and development effort. Late adopters of new production technology may miss the profits generated by increased efficiency. They may thus be hurt by research and development.

Capturing the benefits of research and development. Studies indicate that consumers benefit at least twice as much as producers from public agricultural research and development. The pre-tax benefits to consumers and producers represent an average annual return of 30 to 60 percent on the national public investment in research and development. For the Midwest, the return is higher. The magnitude of the benefits justifies strong public support of these efforts.

Private firms use patents, copyrights, and secrecy to retain proprietary control of their technology as long as possible. They are thus able to capture the benefits of their investment in research and development. It is virtually impossible for individual farmers to capture proprietary benefits of agricultural research and development because their individual operations are not large enough to support effective, separate R&D programs. For example, it would be enormously inefficient for individual farmers to develop crop varieties for their own use. In addition, the results of much publicly supported agricultural R&D are widely disseminated, even to other parts of the world. The United States must cooperate in this information exchange because we need the information, products, germplasm, and human capital being generated in the R&D systems of other nations. This situation fosters competition in agriculture, which of course, brings pressure to bear on the farmer. It virtually eliminates the possibility that U.S. or Illinois agriculture as a whole can achieve a differentiated position (i.e., a separate, exclusive, market niche) in world agriculture. Of course, the consumer of agricultural products benefits from this competitive situation.

How to make R&D benefit the Illinois farmer. A state that funds agricultural research and development publicly can capture some proprietary benefits for its producers by employing three strategies:

- By providing strong support for site-specific and situation-specific research and development, the results of which are valuable to farmers and agribusiness people of that state, are made available to them rapidly, and spill over relatively little into areas outside the state.
- By focusing research and development on the specific crops or types of livestock that are or at least show great promise of becoming important agricultural enterprises in that state

Table 1. *Comparisons of corn, soybean, and wheat yields in the United States and other countries over a twenty-year period.*

Commodity/Country	1960–64	1980–84	Percentage increase
	Bushels per acre		
Corn			
U.S.A.	62	102	65
All others	25	39	56
Soybeans			
U.S.A.	24	28	17
Brazil	15	25	67
All others	12	22	83
Wheat			
U.S.A.	25	36	44
Europe	29	59	103
India	12	25	108
All others	17	30	76

Source: Food and Agricultural Organization of the United Nations Production Yearbook, vol. 38, 1984. Data compiled by L. Frederick Welch, professor, Department of Agronomy.

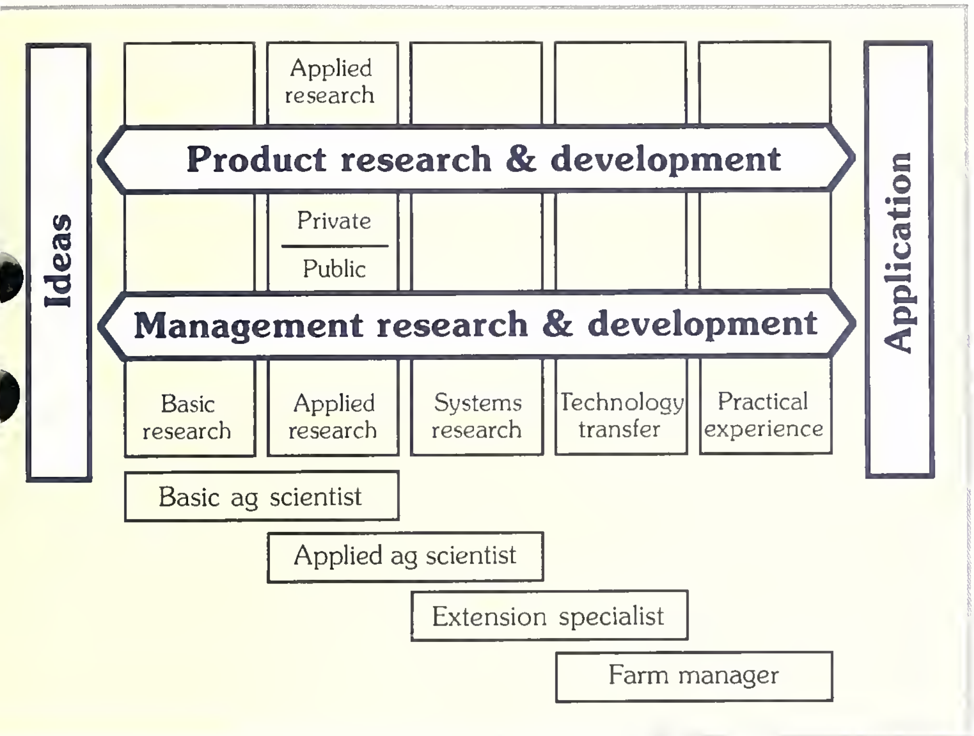


Fig. 1. Basic research in food and agriculture generates many ideas for new products to be used as inputs to agriculture. This research is conducted primarily by the public sector. Once potential products are identified, the private sector will usually conduct the necessary applied research to produce them in marketable form. Then public research institutions usually come back into the process to test and compare the products and identify ways to integrate them into safe, workable, profitable production or utilization systems. After the systems research has been completed, technology transfer must occur. This transfer is ordinarily accomplished directly or indirectly by extension and instruction. Finally, the user must undergo a period of learning and practical experience with the product in order to use it effectively.

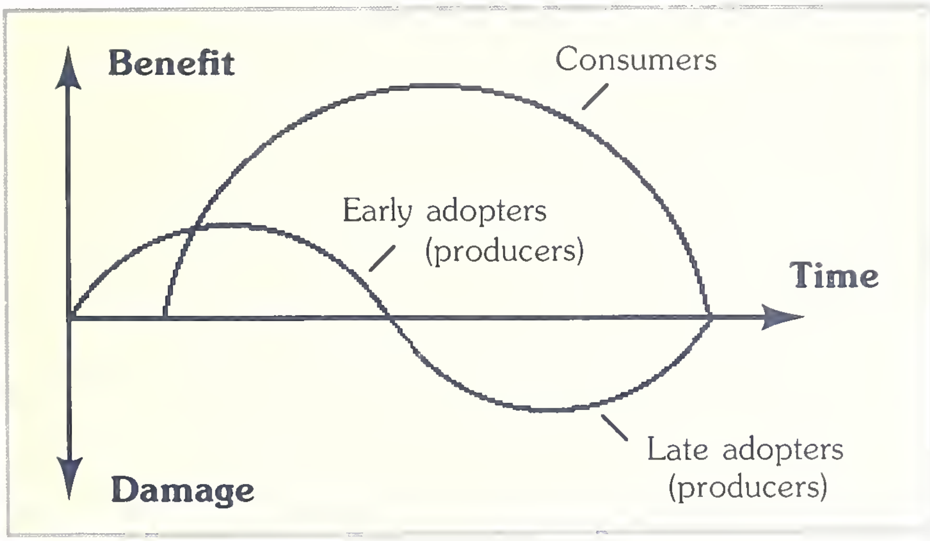


Fig. 2. The beneficiaries of agricultural research, relative to the magnitude and duration of the benefits. The zero point on the time axis represents the time at which a specific, new technology becomes available for practical use. Those who adopt the technology early are the first to benefit. Once producers have begun to use the technology, prices fall, and consumers benefit twice as much as producers from agricultural research and development. Those who are late adopters are hurt by research and development because of the competition created by the resulting technology.

and for which the state has clear comparative advantage.

- By developing a superior communications system among the agricultural interests of the state, so that timely information is exchanged and useful new technology implemented as rapidly and effectively as possible. This system, referred to as the decision support system, must be highly computerized to be competitive in the future.

The corn example. The development of corn production technology classically illustrates the function of the agricultural research and development system. Mechanization expanded U.S. corn acreage greatly during the late 1800s and early 1900s, but average corn yield per acre changed relatively little between colonial times and the 1930s.

Shortly after the State Agricultural Experiment Station System (SAES) of the United States came into being in 1887, agricultural scientists began to study the genetics of corn and to select desirable types in an efficient, scientific manner. In the 1930s, hybrid corn began to be used widely. After that, average yields increased about two bushels per acre per year.

Over the years, scientists from the State Agricultural Experiment Stations and the U.S. Department of Agriculture developed the techniques of hybridization, ear-to-row selection, analysis of genetic variance, recurrent selection, pedigree breeding, disease inoculation procedures, and many other aspects of corn breeding. Armed with these techniques, corn breeders and geneticists have continued to produce new varieties with ever-improving genetic potential for high quality and productivity, resistance to pests and stress, and diversity of use.

But this is only part of the story. When the remarkable increases in average yield per acre began in the 1930s, farmers prepared fields for corn planting by plowing and disking. Manure, limestone, raw rock phosphate and muriate of potash were the standard fertilizer materials. The seed was generally planted in 40-inch rows, three or four kernels per hill. The hills were spaced 40 inches

apart in the rows. This spacing provided a plant population of 12,000 to 16,000 plants per acre. Since there were no chemical herbicides, weeds were controlled by mechanical cultivation. Insecticides were unavailable. Mature corn was harvested with corn huskers or snappers, and the ears were transported to corn cribs for natural drying.

Corn culture in the 1980s is very different. Much land to be planted to corn is prepared by minimum tillage or, in some cases, no tillage. These soil-conserving practices, made possible by chemical pesticides and vegetation suppressants, also conserve energy. Many different, manufactured fertilizers, applied according to soil test, provide readily available nutrients for the corn plants. Corn is usually planted in 30-inch rows, several weeks earlier than it was in the 1930s. The plants may be uniformly distributed in the row or in hills that are less than 20 inches apart. Normal populations run from 22,000 to 30,000 plants per acre. The upright leaves, stiff stalks, and vigor of current varieties permit these higher populations.

Now, farmers apply insecticides when it is necessary to control soil-borne insects. They control other insects with aerial sprays and various biological control measures. They use preemergence and postemergence herbicides that provide superb weed control and minimize or eliminate the need for mechanical cultivation. Fungicides are used when necessary to control fungal diseases. As with other aspects of corn production, the technology of harvesting, storing, and marketing corn differs enormously from the technology of the 1930s.

Although the practices for growing, harvesting, and marketing corn have changed dramatically since the 1930s, the changes have been gradual. If you were to try to watch this change, it would be like watching a clock. Each year, private corn breeders, drawing on corn germplasm and breeding techniques developed primarily by researchers in the Experiment Stations, produce new corn varieties that increase the average yield potential of the crop by two bushels per acre.

To realize this potential, however, farmers have changed their corn production practices. They have been able to do so because Experiment Station scientists have repeated, year in and year out, the experiments that provide essential corn management information.

These experiments include variety comparisons and studies of tillage practices, population and planting patterns, depth and time of planting, and rate and date of application of fertilizers, herbicides, insecticides, and fungicides. In addition, systems experiments are conducted, in which combinations of treatments are compared and the interactions between production factors studied. Also repeated are the experiments that yield refinements in machine design and adjustment. Farm record keeping and management systems are constantly studied, evaluated, and refined by agricultural economists. Extension specialists have continuously conveyed the information from these experiments to farmers, consultants, and agribusiness people.

Not only must the experiments be repeated year in and year out as the genetic characteristics and potential of the crops change, but they must also be repeated for all the new products and in all of the various soil and climatic environments in which the crops are grown. The optimum combination of procedures and products differs on virtually every farm because of the enormous complexity of the soil-crop-weather system and the changing economic status of each farming operation.

Because certain aspects of this research are repetitive and site-specific, the undertaking seems mundane and unglamorous to some people. It rarely contributes to the international reputation of the scientists who perform it. Done correctly, however, it is extremely sophisticated, labor intensive, and costly. But most important, this research is absolutely essential. It is the only research that produces information on which the farmers can act to improve their productivity and efficiency.

The value of the great investment of capital and human resources in basic and early-stage developmental research is never realized until this practical research is conducted, and the practical information is transferred to the user. This is the "bread and butter" research of Illinois agriculture. Experiment Station scientists, their USDA colleagues, and the Cooperative Extension Service have been primarily responsible for this critically important activity.

A parallel example of the role and importance of Agricultural Experiment Station research can be drawn for virtually every crop, animal, and product used in agriculture. By experience, agriculturalists have generated a uniquely efficient cooperative relationship in which private research efforts are focused primarily on product development (e.g., corn varieties). The State Experiment Stations perform the applied and systems research whereby products are evaluated and compared, procedures for their use are refined, and products are integrated into efficient production and marketing systems.

Now new agricultural products and processes are being generated rapidly over the whole world. Research on the agricultural applications of biotechnology and computers is particularly product oriented. These research efforts will result in a proliferation of new crop varieties, animal lines, pharmaceuticals, and decison-aid software items. An enormous amount of publicly supported applied and systems research will have to be accomplished, and equivalent technology transfer will have to occur for us to benefit from the new products. Only then will it be possible for Illinois farmers and agribusiness people to become the early, effective adopters of these powerful new technologies.

If Illinois agriculture, particularly production agriculture, is to remain competitive, the R&D effort supporting it will have to be mounted on a much larger and more technically sophisticated scale than it currently is. We can be the architects of change — or its victims. It's that simple.

Donald A. Holt, director, Agricultural Experiment Station □

Conference Report: Shaping the Future

Robert D. Sampson

For two and a half days in September, 115 farm and agribusiness leaders from all over the state met in Urbana to grapple with the problems facing Illinois agriculture. How should we respond to growing international competition? What policies should we pursue to meet the challenges posed on various fronts? What role should the University of Illinois play in this process? These and other questions dominated the discussions.

The conference, which took place from September 8 to 10, 1986, was sponsored by the University of Illinois (UIUC) College of Agriculture. In his opening remarks, John R. Campbell, dean of the College of Agriculture, said that participants must address two major questions: How should Illinois agriculture best respond to increasing agricultural competition? What role should the College of Agriculture play in helping Illinois agriculture meet this competition?

Faith in the future. "We titled the conference *The Future of Illinois Agriculture*," Campbell said, "because we want to make a statement. At a time when many wonder if Illinois agriculture has a future, our conference title says that we believe Illinois agriculture does have a future."

Campbell said that a "tremendous challenge" confronted conference participants. "But I am confident," he added, "that we will — once again — rise to the occasion and continue to prove that there is extraordinary potential in ordinary people."

When the intensive deliberations and exchanges of ideas were over, it was evident that participants had lived up to Campbell's expectations. They had formulated 10 recommended goals and an equal number of recommended strategies geared to the future of Illinois agriculture. Time did not permit an orderly assessment of the roles the UIUC College of Agriculture should play in achieving the goals and implementing the strategies outlined. However, participants did compile a list of potentially 138 roles, programs, and changes. These will be reduced and arranged in order of priority through mail balloting. The roles, as they emerged at the conference, fell into 10 basic areas. A summary of these is given in the box. (See page 27.)

The end of the conference did not mark the end of the process that had been set in motion — the process of active involvement in the future of Illinois agriculture. Conference organizers from the College of Agriculture see the dialogue between participants and the College as ongoing.

Goals and strategies. The objectives and strategies outlined in the conference and the roles recommended for the College of Agriculture are part of a larger, offensive-minded response that these individuals advocate toward the problems facing agriculture.

The process of active participation in the future of Illinois agriculture began late last spring. At that time, farmers, agribusiness leaders, farm organization representatives, government officials, and educators received invitations to the conference. Potential conference participants were then sent an extensive questionnaire that suggested many goals and strategies. However, participants were first polled on the general approach favored for the problems.

The first part of the survey asked respondents to identify which of three actions — defensive, middle ground, or offensive — they favored. The defensive response was defined as "designed to insulate and protect Illinois agriculture from the destabilizing effects of growing domestic and international competition."

A middle ground approach was "aimed at helping Illinois agriculture hold its own in international competition, but protecting it somewhat from the destabilizing effects of global competition." An offensive approach was defined as one designed

An important, productive feature of the conference on "The Future of Illinois Agriculture" was the small group session. In these small groups, strategies were planned, goals targeted, and the role of the College of Agriculture defined.

"to help Illinois agriculture compete effectively in international markets and capture increased market share, even if it exposes it to the destabilizing effects of growing international competition."

By a wide majority, 84 percent, the respondents found the offensive strategy most desirable. A large proportion, 68 percent, regarded the defensive approach as undesirable.

"The jobs of many agribusiness people depend on maintaining a high volume of business in production agriculture. In Illinois, this means we must be able to export," said Donald A. Holt, director of the University of Illinois Agricultural Experiment Station, who assisted Campbell in organizing the conference. "I felt it was significant that the group tended toward the offensive approach. It demonstrated a willingness on their part to take actions to make our agriculture more competitive. I believe the group recognized that there are risks involved in any response, whether defensive or offensive."

Holt noted that a Farmers and Ranchers Congress a few days later in St. Louis, sponsored by singer Willie Nelson, produced a very different set of recommendations. Participants concentrated more on mandatory production controls and import limits, which would be classified as defensive by Illinois conference participants. Holt attributed the different conclusions in part to a wider representation of agribusiness and consumer interests at the University of Illinois conference.

In the preconference survey, participants expressed support for the statement of mission, which was "to improve and maintain the economic health of Illinois agriculture, using strategies that also protect natural resources and preserve environmental quality, satisfy consumer demand for a safe and secure food supply, and maintain effective, efficient, responsive public institutions."

As it evolved, the conference focused most on ways to improve the economic health and profitability of Illinois agriculture. Relatively little emphasis was placed on issues such as environmental quality, vitality of rural communities and institutions, safety and nutritional value of food. Participants with special interests in those areas expressed disappointment.

"Such questions do call for the same kind of careful consideration given profitability," said Holt. "No one should read into the 10 recommended goals and 10 recommended strategies a rejection of these valid and important concerns. In future strategic planning, we must deal more effectively with these issues."

Guest speakers. Helping to set the tone of the discussions and injecting important ideals into the process were five guest speakers: Richard Durbin, U.S. Congressman for Illinois's 20th district; William Hudson, manager of marketing research for The Andersons; Adlai Stevenson III, former U.S. Senator and then candidate for governor; Dennis T. Avery, senior agricultural analyst for the U.S. Department of State; and Nyle C. Brady, senior assistant administrator for the U.S. Agency for International Development.

Durbin urged farmers and those concerned with agriculture to look beyond official farm policy. Farmers, he said, can be hurt by policies that on the surface seem to bear no relation to farm issues. He gave the example of the U.S. decision to bail out Latin American countries on the verge of defaulting their bank loans. That decision, which provided more capital for foreign agricultural production, curtailed U.S. exports to those countries and increased imports from them to the United States. The decision also created an impact on our farm economy. "The loser in this strategy . . . unfortunately was the U.S. economy in general and our farmers in particular," Durbin said.

Hudson said he did not, in the near future, foresee any reduction in the current world surplus of food. He did predict an end to large farm subsidies. "Our tanks are full, but the (government) is paying. We will have record net farm income, but we don't like the direction it's coming from. Like Indian summer, it can't last."

Stevenson called for the creation of a postharvest technology research center that would find innovative uses for Illinois farm products and create new markets for the state's agricultural production. "There should be more research in developing cheaper, more salable products for food and nonfood uses," Stevenson said. "This research will create new industries, getting more of the 'value-added' dollar for Illinois."

According to Avery, export markets are the key to American farm prosperity. But he warned that continued reliance on farm subsidies is a high-risk strategy that "invites shrinking sales, fewer farmers, and higher farm costs." He said that the high costs of subsidizing agriculture were causing problems for all the subsidizing countries, including the European Economic Community and the United States.

Brady emphasized the need for continued U.S. aid to developing nations, particularly in agriculture. "Sales of agricultural goods to developing countries now account for 38 percent of total U.S. agricultural exports," he said.

Despite the contention of critics, Brady argued, such aid programs build customers rather than competitors. He illustrated this point with extensive data on world trade. Brady indicated that there are relatively few alternatives to international aid. "We can fight wars with these people, provide them free food to keep them from starving, or help them develop," he said.

Summing up. A review of the top ten choices in both the goal and strategy categories reveals a clear emphasis on increased research and development, greater support for applied research, greater support for marketing and utilization, and stronger educational programs to improve managerial skills. (See box.)

"I think it is very important to note that this group recognized research and development as a key component of any strategy to deal with international agricultural competition," said Holt. "I was also interested to learn that the group emphasized the need for improving the decision-support system so that infor-

Top Ten Objectives for Illinois Agriculture

1. Maximize economic returns to capital, labor, and management in Illinois agriculture (farming and agriculturally related businesses).

2. Improve the managerial abilities of agricultural decision-makers at all levels of Illinois agriculture — including farmers, agribusiness managers, and county, state, and federal decision-makers.

3. Penetrate existing markets and/or create new markets for Illinois agricultural products.

4. Improve the speed and efficiency with which Illinois agriculture can respond to change.

5. Improve Illinois's capacity to develop and put into use new agricultural technology.

6. Achieve more product differentiation (more diverse and higher-value products) at the farm level of Illinois agriculture.

7. Make Illinois the lowest-cost producer of quality farm and processed products, filling specific niches in changing markets while preserving our natural resources.

8. Improve business climate for agricultural industries and processors of farm products to draw processors and other agricultural industries back to Illinois.

9. Increase research and development spending to a level similar to that of high-performing states and comparable industries (approximately 2 percent of sales).

10. Maintain the quality and productivity of Illinois agricultural and natural resources.

Top Ten Strategies for Illinois Agriculture

1. Increase research and development efforts on new crop and livestock enterprises, on new uses for Illinois products, on nontraditional enterprises such as aquaculture, and on new management skills to reduce environmental risks to agriculture.

2. Provide a line item in the state budget earmarked specifically for applied agricultural and extension activities that generate and transfer information upon which farmers and agribusiness people can act to plan, implement, and manage profitable agricultural production and marketing systems.

3. Provide effective management skills training for those involved in agriculture and develop cooperative public-private initiatives toward this goal.

4. Establish a computerized information network linking farmers, agribusiness people, government agencies, and agricultural institutions in Illinois.

5. Strengthen technology transfer systems to help Illinois agriculture become an early, effective adopter of new technology.

6. Encourage the development of small industries in rural areas by providing resources for entrepreneurs and training for existing businesses.

7. Eliminate policies that try to deal with social problems by production controls, subsidies, and other programs that affect markets. Implement policies that allow the prices of agricultural products to float to the world-market level.

8. Provide unemployment compensation, relocation allowances, and job training for farmers who are forced to quit farming; and provide safety net programs for dislocated farmers.

9. Develop and carry out an aggressive program to enhance the quality of Illinois crop and livestock products in domestic and foreign markets.

10. Encourage the development of policies that will ensure the availability of capital at competitive interest rates for rural Illinois.

Top Ten Roles for the UIUC College of Agriculture

1. Foster more interdisciplinary programs.

2. Strengthen and redirect the research program as necessary to ensure competitiveness.

3. Change the method of funding publicly supported research and extension to assure support for applied research and technology transfer.

4. Reorganize certain programs in the College of Agriculture.

5. Encourage more cooperation among Illinois agencies, educational institutions, and the private sector.

6. Evaluate and improve the method of managing the public research and development system.

7. Strengthen on-campus and off-campus agricultural education and Cooperative Extension activities.

8. Improve the agricultural information communications network and the agricultural decision support system, in general.

9. Increase research effort on conservation and environmental matters.

10. Mount research and educational programs to reduce the unit costs of agricultural production.

mation can move more effectively and rapidly throughout Illinois agriculture."

The conference featured many small group discussions and a few large group meetings. Although this structure may not have pleased all participants, Holt believes that on the whole, the conference generated much healthy disagreement and lively discussion. Holt added that the conference proved one thing — that "it was possible for this group to reach some degree of consensus on goals and strategies for meeting the problems of Illinois agriculture."

"I think it is clear from the final lists," said Holt, "that even those who represented interests not concerning the majority of participants were still able to influence and help shape the perspectives that emerged."

Fourteen individuals were elected by the conferees at the last session. They plan to meet regularly with College officials to discuss the issues raised and ways in which to incorporate the recommended strategies and goals into the College's activities.

"We ought to insitutionalize the strategic planning process in Illinois agriculture," Holt said. "We ought to do it on a regular, continuing basis and in a way that makes it broad-based.

"Decisions will be made at the county, state, and national levels that will influence the competitive ability of Illinois agriculture. It is extremely important that those making the decisions are working in the context of a clear set of mutually agreed upon objectives and strategies. Otherwise, we may implement programs and procedures that conflict and are not efficient in supporting the interests of Illinois agriculture."

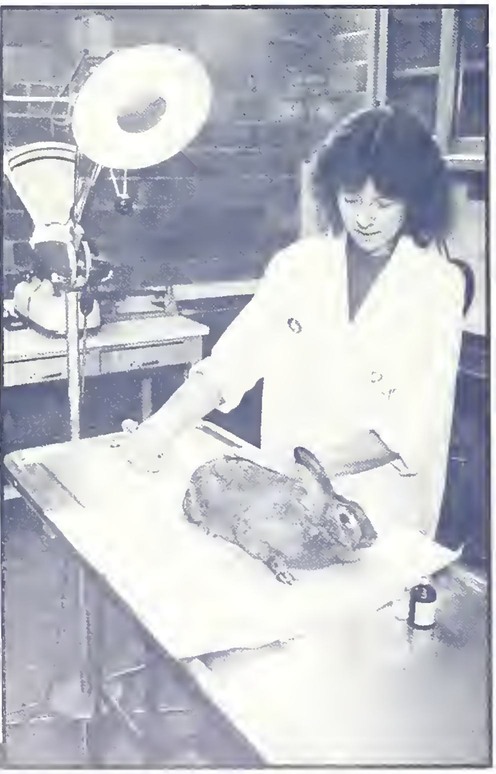
Robert D. Sampson, visiting Extension communications specialist ☐

Animal Health and Productivity in Agriculture

Richard E. Dierks

A strong animal production system is essential to the health of American agriculture. Animal feeds are and will remain the primary outlet for the vast majority of crops grown in the United States. As exports in corn and soybeans decline, the use of these commodities as animal feed increases in relative importance.

Questions of health and productivity will continue to demand much attention from veterinary medicine, but the context will continue to change. In the past, the individual sick animal was the focus of attention. Although that is still true in relation to companion animals and horses today, individual animal health care plays only a minor role in most modern animal production systems. Diseases continue to extract staggering, often hidden, losses in efficiency in many of our production systems. Disease control measures at the herd and farm level must be more effectively incorporated into animal production and management systems.



Building new programs. The goals of the College of Veterinary Medicine are to develop programs in research, teaching, and extension that will meet the new challenges in Illinois's animal agriculture. At the same time, the College feels committed to continuing those programs that are perceived as its strengths. In a number of instances, both strategies will be difficult or impossible to follow. We will require additional resources or we will have to make some hard choices. That is, we may have to abandon productive programs so as to undertake others that are needed more critically.

We must strengthen the links between animal agricultural production systems, research, and disease diagnosis. Molecular biology, immunology, and other basic research will lead to new, improved methods of preventing and detecting animal diseases. Much, however, will depend on the appropriate application of that research by veterinarians and animal scientists. Veterinary epidemiologists in the College must establish accurate, computerized data bases both to identify and to statistically validate economic losses resulting from individual and combined diseases. Accurate animal diagnostic services and field investigation systems are essential and must be continually improved to provide better services to the producer and stronger training programs for future veterinarians.

Combining skills. The College of Veterinary Medicine has initiated a small training program emphasizing integrated food animal management (IFAM). The IFAM program is designed to help veterinarians acquire a combination of skills: in epidemiology, computers, economics, business management, and communications. All these skills will enable veterinarians to apply existing and new information to differing farm and corporate animal production systems. Additional resources, however, will be necessary both to complete this program and to expand others.

The College of Veterinary Medicine has continued to expand its programs related to toxicology in human and animal health. Even though only a small percentage of animal meats reach the market with antibiotic or chemical residues, the public will demand that we do an even better job in this area in the future.

The role of the Extension Veterinarian will need to be broadened so that veterinarians can deliver new techniques and programs to those in animal production. Demonstrations as well as the direct delivery of information will be necessary to help Illinois farmers be among the first to adopt programs that will give them a competitive edge.

International activities in the College will center around the graduate training of foreign veterinarians in the modern production and herd health methodologies that are relevant to their production systems and can be utilized to help reduce and eliminate the impact of animal diseases in their respective countries.

Richard E. Dierks, dean, College of Veterinary Medicine ☐

In Progress

Hatching new technologies

A unique incubator is under construction on the Urbana-Champaign campus of the University of Illinois. The Sponsored Research Incubator Building, scheduled for completion in June 1987, is being built in the South Farms area. This facility, which will cover an area of 11,200 square feet, will house entrepreneurs, fledgling firms, and satellite facilities of established firms. The common goals of all these occupants will be to identify, develop, and market the most promising ideas generated by agricultural research.

Donald A. Holt, director of the Agricultural Experiment Station and member of the incubator's advisory board, expects that the majority of incubator residents will focus on agricultural biotechnology and other aspects of high technology as they pertain to agriculture. According to John R. Campbell, dean of the College of Agriculture, "The incubator will encourage close collaboration between university researchers and private companies and will foster new jobs for Illinois while helping its farmers compete in world markets."

The facility is financed through a grant awarded by the state Department of Commerce and Community Affairs, with matching money from the University of Illinois and College of Agriculture. In presenting the award, Governor James Thompson stated that one of the project's main goals is "to foster close cooperation between the public and private sectors, particularly between universities and businesses."

The incubator will offer its tenants secretarial services and other features normally available in business incubators, as well as offices and specialized laboratory space. In addition, some University facilities and farm areas will be available for testing prototypes under realistic farm conditions. Use of equipment and facilities will be negotiated with each lease.

Entrepreneurs and companies interested in leasing space in the incubator may obtain additional information by contacting the Illinois Agricultural Experiment Station, 211 Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801.

Prepared by Mary Scott Miller, assistant to the director of the Agricultural Experiment Station ☐

University of Illinois at Urbana-Champaign
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Please limit letters to 250 words.

The Cover

The symbiotic relationship that exists among plants, animals, and people is intensified by urban environments. Plants and animals require special care in cities but also make cities livable by constantly reminding us of our ties to nature. The superimposed images on our cover suggest that urban residents create islands of natural environments within cities by electing to live with plants and animals.

"At a time unlike any in the past, we must envision the future."

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The Illinois Agricultural Experiment Station provides equal opportunities in programs.

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Contents

Urban Plants and Animals

Challenges for the Future

This issue of *Illinois Research* shows clearly the importance of plants and animals in the urban environment, out-of-doors as well as inside our dwellings and workplaces. This issue also shows that a number of faculty members in the University of Illinois College of Agriculture are concerned about these living members of our environment. Millions of people live in our urban state, and this College is uniquely suited to play a key role in improving the quality and care of urban plants and animals through our ongoing efforts in research and public education. Special nutritional needs of pet animals have been identified by earlier research here, and research in progress is expected to point the way to additional improvements in pet foods. Outdoor gardening is an important way to maintain contact with nature on the part of both suburban and inner-city residents and is an avenue for some of them to gain self-esteem and an improved diet by producing a substantial portion of their own vegetables during the summer months. There are so many gardeners and prospective gardeners in Illinois that the challenge is for the limited number of professionals employed by this College to train and motivate increasing numbers of paraprofessionals and volunteers who can bring needed information and inspiration to those who can benefit.

Providing plants for urban dwellers is an immense and costly enterprise requiring an extensive network of growers and suppliers. A 1984 survey by University of Illinois Horticulture faculty members revealed that the value of Illinois landscape plants is over $1.6 billion, and the annual maintenance bill is $34 million. Illinois garden center sales were estimated at $1.5 billion annually, and the rapidly growing Illinois interiorscape industry received $40 million from clients for installation and maintenance of plants. Continuing research by College faculty is aimed at improving the efficiency and effectiveness of this network, with millions of Illinois residents being the ultimate beneficiaries. A major challenge for the future is to make available high quality, moderately priced perennial plants that are well adapted to their urban surroundings and to learn how to provide care that will ensure long life. Urban plants that are located out-of-doors must be able to withstand extremes of high and low temperature, drouth, insect pests, and plant diseases; and they must tolerate well the abrupt transition to low light intensity and low humidity when placed indoors. As part of the search for new and improved plant cultivars, there is a pressing need to expand our germplasm collections of landscape plants and to assess these plants' ability to tolerate climatic extremes, insects, and disease. The use of genetic engineering techniques to transfer particular desirable traits from one woody perennial plant to another is presently no more than a gleam in the eye of the researcher, but substantial progress in this area is expected in the years to come.

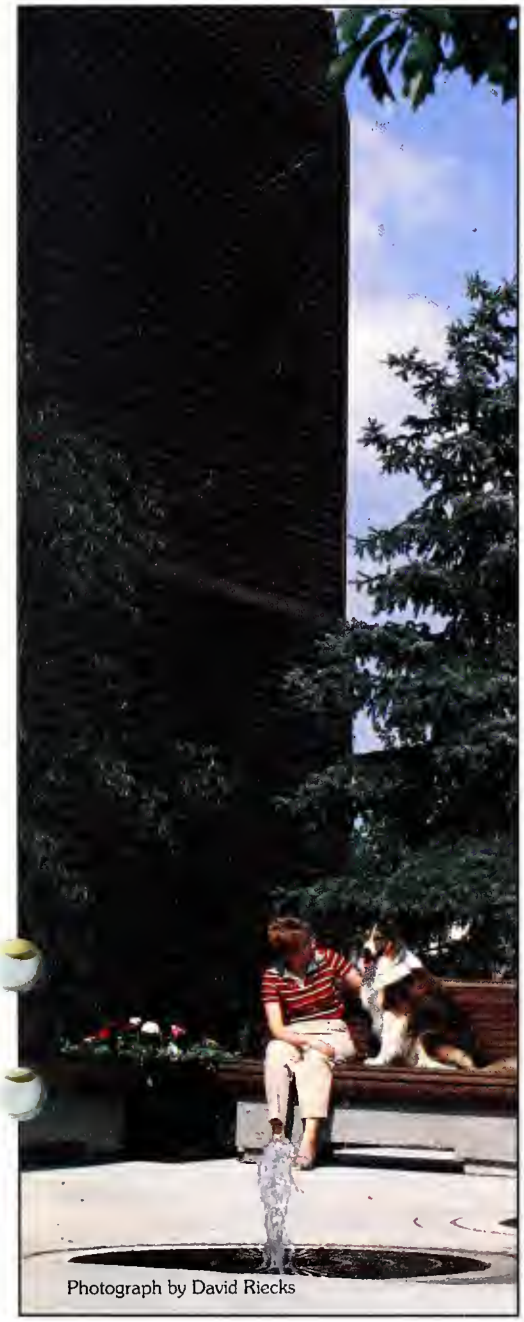
There is also need for improved micropropagation procedures that utilize cell and tissue culture for the rapid increase of desirable new cultivars. For example, successful micropropagation of the 'Marmo' maple was recently achieved by workers in this College. This very desirable shade tree has good fall color and rapid growth, and it is a sterile hybrid of red and silver maples. Research in progress indicates that micropropagation has promise for other shade trees that are difficult to propagate by the usual means of grafting or rooted cuttings. Some trees, such as the white oak, are especially difficult to transplant successfully. Our College research program on this problem recently revealed that plant hormone application stimulates root growth and reduces the shock to transplanted oaks. This promising experimental work is being continued and is expected to substantially alleviate the transplanting problem in the near future.

These are but a few examples of the ways in which College of Agriculture researchers and educators are contributing to the well-being of urban dwellers. A multidisciplinary approach is needed to mount an effective attack on the complex problems concerning urban plants and animals. Such an approach has long been used in this College to spark improvements in agriculture, so an involvement with urban concerns is a logical and productive way to use our accumulated expertise.

David B. Dickinson, professor and head, Department of Horticulture

The Diversity of Roles for Plants and Animals in the Urban Environment

William R. Nelson and James E. Corbin



Photograph by David Riecks

Plants and animals are essential for the survival of humanity. Close relationships exist between people and plants and animals, with plants and animals linked to humans not only in the food chain but also as integral parts of human culture and as elements that historically provide a close bond with nature. Even today, human interactions with plants and animals continue to provide physiological and psychological benefits necessary to maintain our physical and mental health. Quite simply, plants and animals make life possible and worth living.

In this overview, we will touch on some of the important ways in which plants and animals affect our daily lives. Other articles within this issue of *Illinois Research* will develop in more detail some of the key concepts introduced here and will examine specific research findings and their practical applications.

The role of plants. Why, we may ask, should we find it necessary to write about plants and their importance to people in the urban environment? Why should we not rest, secure in the belief that the city provides for people's physical needs, without probing into the more esoteric concerns about their needs as biological organisms? After all, the city's architecture will shelter us, the supermarket will feed us, and the water department will satisfy our thirst — what more can we ask for? Well, the issue is not if the urban environment satisfies our most basic needs, but if the urban environment can be designed and managed to foster human experiences of satisfaction and pleasure, which so richly enhance the individual's quality of life.

Ties to nature. It is important to recognize that the physical environment has a profound impact on a person's life. We cannot cut ourselves off from our physical environment: it is the substratum of our daily lives. Rene Dubos, in his book *So Human an Animal,* states, "Since human beings are as much a product of their total environment as of their genetic endowment, it is theoretically possible to improve the lot of man on earth by manipulating the environmental factors that shape his nature and condition his destiny." Among the many environmental factors that may be "manipulated," plants should not be overlooked. Plants have had a prominent role in human environments since the beginning of recorded time.

Contemporary human bonding with plants can be seen everywhere — from the potted plant on the windowsill or the office desk to the community vegetable gardens and the plantings of trees, shrubs, and flowers in public and private spaces. And yet, with the exception of the community vegetable garden, none of these plants is grown for what it yields in food or shelter for human beings. Rather, these plants provide a source of pleasure to the human grower and observer.

Another compelling reason to cultivate plants in our cities is that plants

are one tangible link that permits us to reaffirm our biological connection to nature. And, according to Yi-Fu Tuan in his book *Topophilia*, the presence of plants wherever people can have that flowerpot or window box is a further expression of the "sentiment for nature and rural ways fostered by the pressures of urban life."

Other roles. Beyond the deeply seated biological tie between people and plants, plants in the urban environment fulfill other significant roles. It can be argued that, if for no other reason, plants should be used in the urban setting because of the practical functions they perform. With proper planning and design, plants may solve or in many ways ameliorate various urban problems relating to pollution, climate, engineering, and the structuring of the landscape's architecture. In the plants' natural processes of photosynthesis, carbon dioxide is absorbed and oxygen released into the atmosphere, mixing with the polluted air and diluting it. Also, the plants help to reduce dust, airborne dirt, fly ash, and fumes by trapping and holding these particles on the leaf and stem surfaces .

Climate is modified in several ways. Temperatures are reduced both as the result of the shade cast by plants and by the energy involved in the process of photosynthesis. Appropriately enough, photosynthesis is referred to as nature's air conditioning system. In addition, pleasant breezes can be amplified and objectional wind can be blocked through proper selection and placement of plants. Efficient energy utilization through management of summer and winter solar exposures can have positive economic returns.

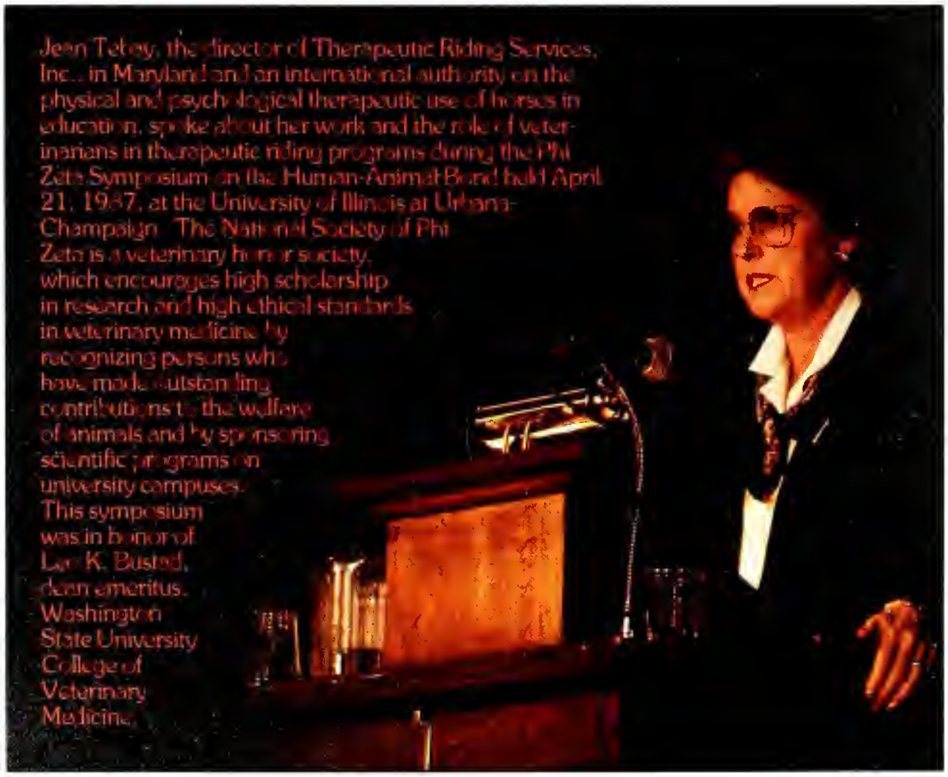
Problems related to what may be called engineering concerns include soil erosion, glare from the hard surfaces of the urban landscape, and management and control of both pedestrian and vehicular traffic. In each case the negative impact of the problems can be minimized or eliminated when trees and shrubs are thoughtfully selected and integrated into the design.

Humanizing the urban landscape. The landscape's architecture is designed to emphasize that outdoor spaces must be scaled, arranged, and detailed as carefully as are the spaces within buildings. As human beings we are spatial animals. We exist (that is, we live, work, shop, and play) in the spaces formed by the placement of buildings, roads, and all other physical objects located on the land. To humanize these spaces and make them more accommodating to human activities, plants can be used in an architectural manner to provide enclosure, privacy, spatial organization, and logic to the many large, overscaled urban spaces.

Obviously the diversity of roles that can be assumed by plants is greater than most people realize. It is important to note that not only can plants perform practical functions but with good design these same plants can also enhance and add beauty to the urban scene. And the benefits accruing from the functional and aesthetic use of plants go beyond the human dimension; studies have shown quantifiable social and economic benefits for both private and public sectors of the city.

Pets — companion animals. Animals as well as plants provide an important link between humans and nature. A cursory reflection will confirm that interactions with animals, too, are part of the daily routine for most urban residents.

Our current perception of the strong bond between animal confidants and humanity has come a long way from the beliefs of a half-century ago, when dogs and cats were regarded as belonging in and around barns and fields on the farm. In those days, young people on the farm were usually accompanied by dogs to the creek bank and fishing; or, on returning from school, they found their devoted dogs waiting with happy, tail-wagging confidence. Enthusiastic acceptance from a pet could always be depended upon, and there was never criticism from the pet. During those early transition years, when a large percent of the population was rural, dogs and cats were banished to living outside and associating with "other" farm animals. Most dogs and cats were diseased and parasitized and certainly not welcomed into the home, which often did not have electric vacuum cleaners or other modern conveniences. Even when dogs became yard dogs, primarily their food was leftovers or table scraps; even then, however, a strong link existed between the dog and the homemaker, who always managed to have just enough leftover food for the dog.



Jean Tebay, the director of Therapeutic Riding Services, Inc., in Maryland and an international authority on the physical and psychological therapeutic use of horses in education, spoke about her work and the role of veterinarians in therapeutic riding programs during the Phi Zeta Symposium on the Human-Animal Bond held April 21, 1987, at the University of Illinois at Urbana-Champaign. The National Society of Phi Zeta is a veterinary honor society, which encourages high scholarship in research and high ethical standards in veterinary medicine by recognizing persons who have made outstanding contributions to the welfare of animals and by sponsoring scientific programs on university campuses. This symposium was in honor of Leo K. Bustad, dean emeritus, Washington State University College of Veterinary Medicine.

As people moved from rural areas to become concentrated in urban housing, dogs and cats also moved from the barnyard to fulfill the role of companion animal. With the development of efficient vaccines, biologicals, anthelmintics, and pet litters, and our increasing knowledge about nutrition, dogs and cats departed from highly undesirable parasite-ridden and diseased conditions into clean, healthy environments and an almost complete dependence on their human associates. Licensing and leash laws, plus competition with automobiles, have forced pets into houses and apartments. In fact, after entering some apartments, many dogs and cats never leave, except for occasional exercise or trips to veterinary clinics. With decreased exposure to feral animals, America's companion animals have never before achieved this superior health status.

Child's best friend. Companion animals provide a learning basis for youngsters that is not available from any other source. The baby growing up with a dog or cat has a constant, interacting companion who provides many facets of companionship and security. Children need love, affection, and attention without rejection; when children return from school or errands and their eager dog or cat greets them, there is total acceptance — never rejection. The all-approving dog bolsters the youngster's ego and provides inner confidence.

Children identify with living animals and participate in a wide world of experience. Youngsters associating with pets become responsible and assertive; this helps develop mature organization, which carries over into schoolwork, part-time work, household duties, and daily activities. Association with pets helps educate youngsters in biological areas of nutrition, reproduction, physiology, and disease control.

Adults need pets, too. Pets lessen the loneliness experienced by many adults in stressed, broken, and celibate homes; in many instances, companion animals become surrogate children or spouses, replacing loved ones no longer present.

Pets also help prepare parents-to-be for the role of parenthood; and experiences associated with the pet's mating, gestation, lactation, and weaning help stabilize expectant parents.

Pets are also time-consuming; yet they are receptive recipients of the owner's mental and physical energy during feeding, grooming, exercising, play, and just plain companionship.

Companion animals provide a social copula, projecting multiple images, including that of social seeker, matchmaker, "good ole' Joe," or "tough guy." Consciously or not, the pet's owner can also use the animal to project an aura of aloofness or gregariousness, as well as all levels of status. Pets provide outlets for frustration and competition, including jealousy.

Because humans eat, sleep, study, and assemble according to the clock, pets also often conform to those time schedules, within physical contraints, and in addition are free to roam through the house or yard and indulge in their pleasures, unrestricted by social mores. Many humans even become jealous of their pet's free time, a perhaps extreme example of our tendency to anthropomorphize, that is, to assign human qualities to animals. This tendency helps emphasize the surrogate role of social and physical dependency on the pet.

Today's pets. Environments have changed since dogs were kept in rural situations; and without modern vacuum cleaners, biologicals, parasite controls, and superior commercial nutrition, companion animals in apartments would be difficult to control.

Overall, the number of cats has exceeded the number of dogs since dogs are banned from many apartment complexes and cats can adapt easily to apartment living and standards of cleanliness. A recent survey found that 42 percent of all cat owners keep cats because of loneliness and 33 percent keep them because they love cats. Many indicated that "cats make a house a home."

Changing demographics, plus increases in information about both mental and geriatric treatment methods, have propelled companion animals into new roles in companionship and the treatment of mental stress. America's 50 million dogs and 51 million cats have become valuable confidants and help make the world a better place in which to live.

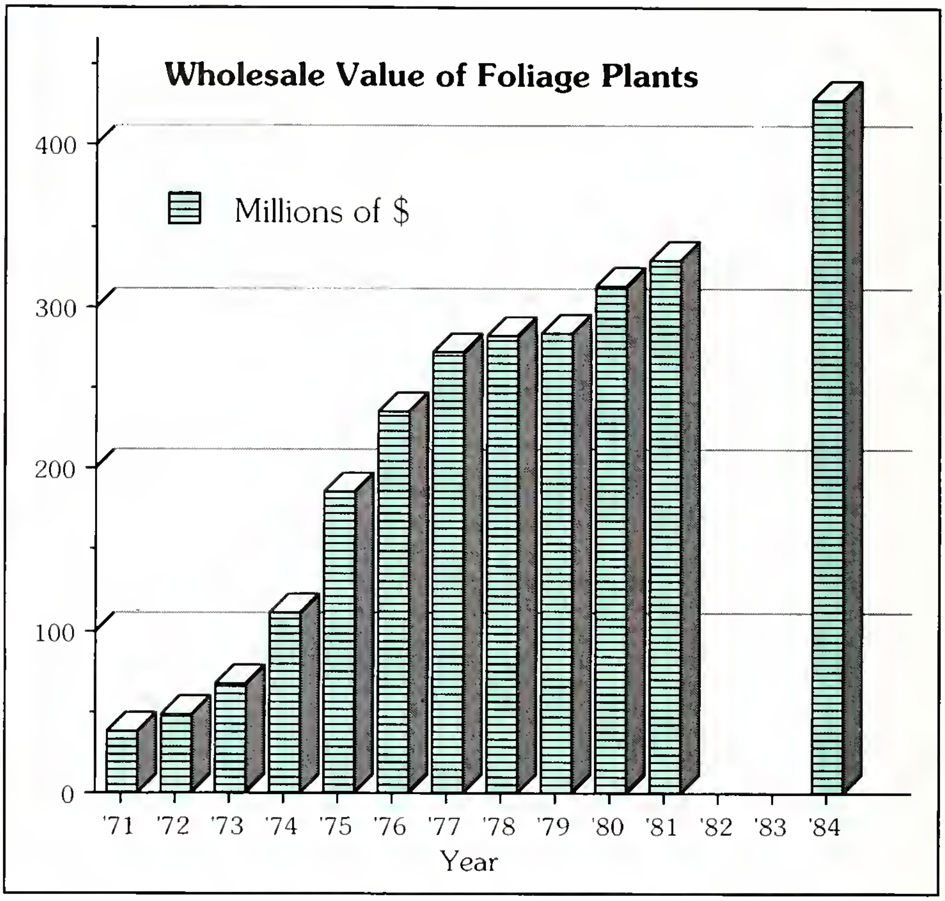
Therapeutic pets. Since our earliest days, pets have brought love, affection, relaxation, pleasure, assistance, and protection; they help preserve our sanity and good health.

Capitalizing on these effects, many psychologists and psychiatrists use animals in therapy, with 94 percent of those who use animals as adjuncts to therapy using dogs and 70 percent using cats. Therapists have discovered that the animal's mere presence can lower a person's blood pressure, convey security, provide companionship, and make life worth living for some people who might otherwise have given up in despair. The Delta Society, which consists of workers who recognize and utilize the value to their human patients of animals in therapy, is the largest of many organizations advocating and using animals to help provide nonjudgmental communication links and bonds with people of all ages.

Dogs and cats are the only major animals removed from the wild, other than as prisoners, to become domesticated in human households by means other than enforced servitude and now almost totally integrated with or dependent on humans. No other domestic animal has altered its whole way of living as radically as has the dog during centuries of "domestication." Concurrently, the cat has, perhaps, altered its life less than has any other domestic animal. The cat generally maintained its wild status through the centuries while taking up residence in people's houses, apparently because there were more mice in houses. Modern dogs and cats rely almost totally on people to meet their needs. Similarly, many humans rely on their animal confidants for extremely close relationships and ties to nature.

William R. Nelson, professor of horticulture and Extension landscape architecture, and James E. Corbin, professor of animal science, emeritus □

In recent years, green plants have become an integral part of commercial designs for buildings. Here, for example, diners at the River Station in Peoria can enjoy a greenhouse atmosphere.



Adapted from *Flowers and Foliage Plants, Production and Sales*, Sp. Cr. 6-1 (1972-1979), and *Floriculture Crops*, Sp. Cr. 6-1 (1980-1982, 1985), U.S. Department of Agriculture, Washington, D.C.

Interior Landscaping

Dianne A. Noland

A business firm builds a new structure — an office complex, a mall, a bank, or a hotel — and wants to make the interior come alive. A family decides that its home needs a new look to liven up the interior. The solutions may be provided by an interior landscaper or "interiorscaper," a specialist who will help match people with the plants suited to their needs.

Essentially, the interior landscape serves the same functions as the conventional exterior landscape in that it softens architectural lines, adds beauty to the setting, and creates a comfortable environment for those living or working indoors. In fact, psychologists maintain that people have an instinctive need to associate with plants and that plants and flowers in the interior landscape will help to meet this need. Estimates suggest that we spend as much as 70 to 80 percent of our lives indoors, yet only recently have plants begun to play a significant role in the interior landscape.

The green plant and interiorscape industry is a phenomenal success story. From 1959 to 1970, the industry showed stable, if modest, growth from $24 million to $27 million in wholesale value, according to the United States Crop Report Board. Then came the tremendous growth of the 1970s. The environmental movement nurtured an awareness of nature and a desire to bring plants into homes and personal lives. Even the recession of the early half of the 1970s did not injure the industry. Instead, diverted from many expensive pastimes, people turned to gardening, both indoor and outdoor, in great numbers. The wholesale value of the green plant-interiorscape industry in 1978 commanded a $280-million figure, up nearly 968 percent in ten years. Value of the industry continues to rise and is now estimated at over $430 million.

The interior landscaping industry contributed in a large part to this "green plant" explosion. Businesses, especially, wanted plants indoors but did not have the expertise to properly maintain them. Illinois firms led the way in filling this need. One of the first interior landscaping firms in the United States, the Leider firm of Prairieview, continues its success today.

So the next time you stroll through a veritable plant paradise in your neighborhood bank or shopping mall, remember that it wasn't always that way. Plants and people belong together!

Dianne A. Noland, lecturer in the Department of Horticulture □

Inner-city residents can also enjoy gardening.

Urban Gardening

James C. Schmidt

Unoccupied land in the city has a way of attracting trash, bottles, bricks, and weeds. But many city gardeners have welcomed the creative challenge of turning a vacant lot into a garden and making maximum use of limited space to yield the greatest possible quantity of vegetables. For example, residents in Cook, Madison, and St. Clair counties took on this challenge, turning vacant land into backyard gardens and community plots in an effort to produce their own food. Through special extension programs like Urban Gardening and the Consumer and Homemaking Education Program (CHEP), teams of professionals, paraprofessionals, and volunteers teach people in cities how to plan, plant, and care for a garden.

Why a gardening program? Characteristically, the diet of families with limited incomes doesn't include many fresh vegetables. For homemakers in such families, there is a basic need for them to provide fresh food for the table to improve their diet and nutrition. There is also a need to learn — or relearn — how to preserve food for later use. Through urban gardening programs, these families are taught to grow their own food and save money on food costs.

Delivery of the programs. Teaching how to garden integrates the expertise of horticulture and home economics. Topics for training sessions range from gardening techniques, container gardening, and variety selection to nutrition basics and how to prepare and cook unfamiliar vegetables. Traditional group meetings are often held, but more commonly a lesson is given to a small group at a community center or church or one-to-one in the homemaker's kitchen. A successful educational tool is the use of demonstration-teaching gardens that show proper mulching techniques, new varieties of vegetables, space-saving ideas, a sample family garden, or other gardening practices. The emphasis is on teaching how to garden. The professionals involved do not tend the plants, nor do they merely supply seeds, plants, and other materials. They do, however, work with donors to provide plants, tools, fences, hoses, or other equipment for gardeners who can't afford them. This involvement facilitates interagency and business cooperation in the community in a project that offers widespread benefits.

What are the benefits? The tangible benefit of urban gardening is, of course, the dollars saved on the food budget and the supply of fresh vegetables during the growing season. For a homemaker whose food stamps run out by the middle of the month, the significance of having fresh vegetables from the backyard garden when there is no other food in the house is both real and welcome. But the urban gardening families will also tell you of the intangible benefits. For children, gardening is a way of learning where food comes from and how plants grow; for the elderly and underprivileged, gardening allows them to be part of something that provides sharing and communication within their peer groups; to those who are disabled physically or mentally, there is therapeutic value in working with the soil and caring for growing plants. Gardening provides people who have had few successes in life an opportunity to be successful. It instills a sense of responsibility and allows for personal creation and achievement, which build self-confidence and self-respect. It brings families together, provides opportunity for recreation, and builds survival and leadership skills. Through urban gardening, many families and individuals are sharing the spirit and community pride that come from working with each other.

James C. Schmidt, associate horticulturalist in Extension

Grass in the Landscape

Floyd A. Giles

Traditionally, grass has been used in the landscape as a ground cover and a means of erosion control. It fulfills these uses very well and also provides a cool, clean play surface and a uniform, flat element on which to set other landscape plants. Within each geographical region, a small number of turfgrass species has been bred and selected for turf use. Although traditional decorative grasses like pampas, ribbon grass, and blue fescue are still popular, many other species of decorative grasses have also become very popular with landscape designers, horticulturists, and the general public. Today, with many more ornamental species available — ranging in size from a few inches to 20 feet tall — grass can be used for more than a foundation or base for other plants.

Ornamental grass can be used as shrubs, ground covers, and screens. Many of the ornamental grasses form clumps that make them ideal for borders, hedges, screens, and specimens. The wide range of colors, textures, and sizes makes grasses ideal for emphasizing bed lines and enhancing the landscape design. In many new landscapes, ornamental grasses are being used to express the vertical element of the design as well as the horizontal.

Selecting varieties. Selecting ornamental grass for a particular landscape job at this time is not as easy as selecting a shrub or a flower. Not many references or individuals can recommend which grasses to use in a particular location or how to grow them. Other problems are how to propagate and how to plant an area. Some grasses are annuals and need to be seeded each year; some are perennials that are not hardy and that should be overwintered indoors. Many grasses don't make much of a visual impact in winter; but a few, like pampas grass and erect plumed tussock grass, carry their seed heads through winter and can be very spectacular.

Many Midwest soils are heavy and have poor internal drainage, because most are prairie soils. At construction sites, soil is further compacted by heavy machinery, and in public areas by traffic. Compared to shrubs, grasses are better adapted to such compaction because their thick, fibrous root systems grow fast and adapt to changing soil conditions. Many grasses like bamboo and reed-canary grass require or prefer a very wet soil.

Public landscape areas such as parks and zoos need abundant grass growth, large size, and quick regrowth to repair damage caused by traffic and consumption by animals.

Three good locations in the Chicago area to see ornamental grasses are the Chicago Botanic Garden in Glenco, the Cantigny Gardens in Wheaton, and the Brookfield zoo (Chicago Zoological Park). (See the map on pages 14 and 15.) The Missouri Botanical Garden in St. Louis is another good place to view grasses. Justin C. Harper, horticulturist for John Deere in the Rock Island area, grows many ornamental grasses in his private collection. A collection of grasses will also be established at the University of Illinois during 1987.

For the gardener interested in ornamental grasses, a starting point can be

Varieties of Ornamental Grass

1. *Arundo Donax*, Giant Reed. Hardy through USDA Zone 7 (Refer to the map on page 14.). It will usually overwinter in the Chicago area, but will winter-kill. It is always best to store a few clumps that can be divided in the spring. Leave in clumps and divide the eyes in the spring. This plant will reach 20 feet in height in good locations; it grows very fast, making a quick screen.

2. *Cortaderia Selloana*, Pampas Grass. Pampas grass is the best known ornamental grass. In the northern part of its range, it is sometimes frozen out if not protected. Planted in good, well-drained soil and in a protected site, it should be no problem. These plants must be propagated by division, starting with a good-sized plant.

3. *Festuca ovina 'Glauca,'* Blue Fescue. It is hardy through Zone 4. This small blue clump makes a great border or a tufted ground cover, giving a quilted look. Best propagated by seed, it will stand some shade, but the color is better in full sun.

4. *Helictotrichon sempervirens*, Blue Oat Grass (sometimes called Russian oats or avena sativa). This grass is a beautiful light blue and is 2 feet tall and stiff. It makes an outstanding border or a quilted mass planting. It is perfectly hardy through Zone 5. For best color, keep in full sun. It must be propagated by division.

5. *Hordeum jubatum*, Squirrel's-Tail Grass. This grass makes a 2-foot clump that has large seed heads. This perennial will tolerate a wide range of soil and is hardy through Zone 5.

6. *Hystrix patula*, Bottlebrush Grass. This perennial grass does very well in partial shade and is large enough (3 to 4 feet tall) to be a good specimen when used as a single clump. Very well adapted throughout Zone 4.

7. *Miscanthus sacchariflorus*, Eulalia Grass. This tall (7 to 10 feet) perennial grass can be used as a screen and remains effective throughout the winter. The silvery white seed heads remain much of the winter. It is hardy throughout Zone 4.

Striped Eulalia Grass
Miscanthus sinensis 'Variegatus'

the accompanying list of 15 grasses, which will provide a wide range of colors, heights, and textures and which tolerate a wide range of soil types and moisture.

Propagation methods. Ornamental grasses propagated by division cutting or sprigs should be planted in early fall or early spring. Early fall planting is probably best for all of the divided hardy grasses because they have enough time to root down and provide a good plant by the next growing season. Plant less hardy or more difficult to establish grasses like the pampas in early spring and use large, well-rooted plants. Biennial grasses should be planted in early fall. Seed propagation of most of the ornamental grasses should be done in a cold frame or a greenhouse, the same as is done for bedding plants. A few of the grasses, like red fountain grass, will need to be carried over winter in a greenhouse and divided and grown to a 10- to 18-inch plant before being moved outside. Green fountain grass also benefits from this means of reproduction (especially if green and red fountain grass are to be grown together), because it allows for the plants to start even and very little replanting will be required.

Care and maintenance. Establishing grasses should be done with the same care that is used for bedding plants. The better the soil, drainage, and fertility, the better the grass will be. If conditions are not ideal, however, grasses have a better chance of surviving and providing a good show than do most landscape plants.

Grasses are well adapted to the Midwest's humidity, hot summer, and heavy prairie soils. If you need a landscape plant to fill a large bed in a less-than-perfect site, consider one of the ornamental grasses.

Maintenance of grasses can vary greatly from plant to plant. Some will need to be contained so they don't invade other plant areas. Plants grown just for the foliage — for example, the blue fescue — will need their seed head removed. Others may benefit from trimming back if they are suffering from damaged foliage due to sunburn; and some just look fresher if they are cut back and allowed to grow. Some of the larger grasses get too thick and can benefit from a trimming. It is easier to control weeds in grass plantings than in beds of broadleaf plants. Mulching is still a very good procedure to control weeds, but it also aids in the quick establishment of the grass clump. More herbicides can be used to control weeds in grass than can be used in shrubs. Lawn herbicide drift does less damage to grass plantings then it does to broadleaf plants, which can be a great labor-saving feature of landscaping with grass.

Today, with the trend toward making landscapes as low maintenance as possible, growing ornamental grasses offers an opportunity to reduce maintenance and still have good visual quality. Ornamental grasses interject a texture into the landscape that cannot be achieved with other plants.

If you are a grower, designer, retail business, or individual home owner, I am sure you could improve the appearance of your landscaped area by the use of ornamental grass. Also, those of you who manage large areas like golf courses, parks, or zoos, look around you; I am sure that you will find a place for ornamental grasses.

Floyd A. Giles, professor and Extension specialist, Department of Horticulture

8. *Miscanthus sinensis 'Variegatus,'* Striped Eulalia Grass. A three-color, striped grass (yellow, white, and green) is always useful; and with its 6-foot height, it is quite striking. A very hardy perennial grass.

9. *Miscanthus sinensis 'Zebrinus,'* Zebra Grass. This variety is the most striking grass because of its unusual horizontal yellow stripes. This tall, 7-foot grass will work well as a specimen. It will take some shade, but color fades. It is good through Zone 5.

10. *Molinia caerulea 'Variegata,'* Purple Moor Grass. This extremely hardy striped grass is very useful as a border or mass planting because of its growth habit and height (2 feet). It must be propagated by divisions.

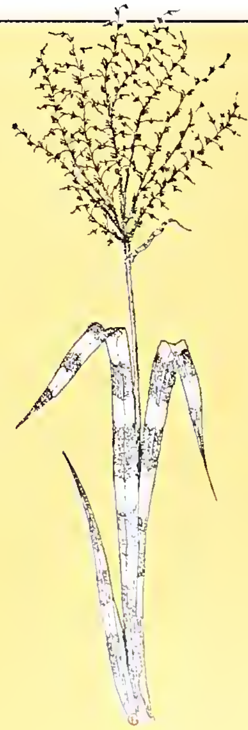
11. *Pennisetum alopecuriodes,* Fountain Grass. Three to 4 feet in height, this is the most popular of all annual grasses. It makes excellent borders and mass plantings. The green form of fountain grass is propagated by seed or divisions.

12. *Pennisetum setaceum,* Crimson Fountain Grass or Red Fountain Grass. The growth habit and the appearance is the same as the green form. The difference is its outstanding, deep red color; and it must be propagated by division. The two fountain grasses make a beautiful combination.

13. *Phalaris arundinacea 'Picta,'* Ribbon Grass. This is one of the grasses that can become invasive, especially in planting beds, so use it accordingly. Its clear white stripes and clean appearance still make it a favorite. It needs to be propagated by division. Hardy throughout Zone 4.

14. *Spartina pectinata 'Aureo-marginata,'* Cord Grass. Cord grass is propagated by division. The leaves of this grass are edged with yellow, which makes it a large background plant. This plant should be planted in well-drained or sandy soil through Zone 5.

15. *Uniola latifolia,* Spangle Grass. This grass is used as much for its seed as for its foliage, both of which will last well into the winter. It should be propagated by division and seeds. A good hardy perennial.



Zebra Grass
Miscanthus sinesis 'Zebrinus'

Landscape Architecture

Robert B. Riley

Americans have long been proud of their green and spacious cities. The great urban park systems of the turn of the century and the manicured lawns and shade trees of our residential districts might well be remembered over the centuries as this country's greatest contribution to landscape design and urban planning. Over the last five years, however, an influential movement among our landscape architects has begun to complement, even redirect, this tradition by applying our increasing knowledge of ecological systems to the design of the urban landscape. This ecologically based design first came to notice in the late 1960s in the work of Ian McHarg, but for many years was mostly applied to nonurban areas. Now it is reaching from the countryside into the very heart of our cities.

On the largest scale, for example, Dallas has completed an ecological study of its entire metropolitan region and developed an open-spaces plan based upon the results. A most dramatic example of this approach is that of Stuttgart, Germany, which has long suffered severe air pollution. A far-reaching forestation plan, based on detailed analysis of the air patterns of the entire metropolitan region, has provided great planting corridors — reaching into and through the city — that have altered both the climate and air quality. This role of vegetation design and planning in modifying urban climate has also been studied and partially implemented, on smaller scales, in Dayton, Ohio, and Davis, California. On an even smaller scale, landscape architects are using both ecological images and ecological analysis in traditional design models. Fountains in the cities of Portland and Seattle, for example, have been based not upon monumental statuary and ornamental jets but upon images of the boulders and waterfalls of the nearby mountains. In Philadelphia, a pair of designers are seeking in natural systems a clue to more stable and healthy planting schemes for the most urban of situations; an example is alley planting using the plant community of the narrow, shaded stream valleys of the region.

Critical to this new approach is the view of urban vegetation as a functional, comprehensive ecological system rather than a fragmented adornment of the urban fabric. Increasing mortality rates for street trees under severe urban conditions of inadequate drainage, compacted soil, and pollutants are being partially counteracted by new planting techniques. More radical, however, is the replacing of the traditional ribboned street and plaza plantings of a single species with a botanically varied system of green corridors weaving through the city. Freeway and railroad rights-of-way often have conditions much more tolerant to greenery than are the heavily used streets in the center of the city, and such plantings also provide a welcome visual relief to some of the most ugly parts of our urban complex. Designers question if our image of the traditional urban park with great, isolated trees rising from the smooth greensward, an image descended from our English pastoral heritage, is the most appropriate solution for many urban situations. These traditional park designs are open ecological systems, requiring a great amount of natural energy and human labor to maintain them. Alternative forms, often called "urban wilds" or "urban forests," are based upon plant communities and ecological regimes that would naturally be found in the area of the city concerned. Although these new forms are not amenable to some traditional uses, such as field sports, they are particularly suitable for others, from nature study to the use of urban trees as a harvestable resource.

Urban wildlife plays its part in this new vision as well. A planned and integrated vegetational system offers new opportunity for attracting and supporting diverse wildlife, most of which have been driven out of our cities to be replaced by a very few forms, such as starling and squirrels. (The density of squirrels in some parts of our cities, for example, has been shown to be many times that of a typical natural woodland regime.) A growing knowledge of wildlife ecology allows the landscape architect to design the shape, size, edge condition, and species balance of urban vegetation so as to attract a far larger diversity of song birds and small animals. Such new species should not only be a pleasure in themselves but also will serve as competitors for the less desirable species. Because such habitats are often unavoidably small in size, the key is to provide continuous corridors of vegetation linking the urban sites to the larger, more natural area around the city: wildlife highways from the countryside into the dense city.

Underlying all of these new views is one principle: that urban nature is not something added to a city, but a total functional and psychological infrastructure, as essential to our urban life as sewers, electricity, streets, and buildings. As such, urban nature can help solve many urban problems, such as climate modification, pollution control, flooding, and water quality — by partly replacing costly, high-technology engineering solutions that often only create new problems. It also offers a new range of beauty and human satisfaction as essential to our life as buildings and plazas.

Robert B. Riley, professor of landscape architecture and architecture □

Park Systems and Open Spaces in the Urban Environment

Robert D. Espeseth
and Thomas J. Burke

The character and liveability of a city are largely determined by the nature and arrangement of its parks and open spaces. These are the "threads" that hold the "urban fabric" together — threads, which may follow natural linear patterns, like streams, rivers, and lake shores to form a network of interconnected waterways. Parks, parkways, walks, trails, and nature preserves may be woven into this fabric.

To meet normal recreational needs, the typical hierarchy of urban parks includes neighborhood, community, city or regional parks, and special areas, like zoos, botanical gardens, arboretums, and planetariums. These open spaces contribute refreshing breathing space and visual relief from the city environment. Ideally, major parks and open spaces — usually thought of as neat blocks of land bounded by city streets — could be linked to create "linear recreationways." Most often these linear recreationways will be in public ownership, but as urban land becomes more scarce and open space more precious, other alternatives, such as utility easements, abandoned railroads, flood plains, canal tow paths, and flood levees can be used to incorporate them. Studies have found that the best open space resources of Illinois lie in relatively narrow, rather unique linear patterns known as "environmental corridors." When combined in such corridors, water, topography, woods, wetlands, and cultural features provide the most significant potential for recreation and open space.

The concepts of linear recreationways and environmental corridors are manifested in our most heavily populated urban areas. For example, ninety percent of the thirty-mile Lake Michigan shoreline in Chicago is under the control of the Chicago Park District and used for a wide variety of recreational, cultural, and open-space needs. There is not another major metropolitan area in the world that has this degree of use and control of such an outstanding linear resource. Another example is the Forest Preserve District of Cook County, which is a system of almost 70,000 acres of open space and recreation land within the most populous county in Illinois. Much of this land is located along the corridors of the Salt Creek, Des Plaines, Chicago, and Calumet rivers, which in addition to providing opportunities for recreation also provide flood plain control in heavily urbanized areas.

Districts serving Illinois.

Illinois has the most comprehensive package of legislation relating to parks, recreation, and open-space preservation in the United States. Through special district opportunities, the needs of citizens of this state are served by park districts, forest preserve districts, conservation districts, river conservancy districts, or a combination of several of the districts at different governmental levels. As an alternative, communities may provide park and recreation services through a department directly under the municipality. In the preceding examples, the residents of Chicago are served by the Chicago Park District at the local level and by the Forest Preserve District of Cook County, which also serves the rest of the county. These are two of the largest agencies of their types in the country, with large budgets and staffs providing very comprehensive services to residents and visitors.

Highly urbanized, northeastern Illinois is served by the greatest concentration of park and recreation agencies of any comparable area in the country. The quality of service is attested to by the fact that Illinois agencies have won more gold medals for excellence from the National Recreation and Park Association than any other state. These agencies are leaders not only in innovative recreation programming but also in comprehensive policy formulation.

Revitalizing waterfronts. Park and recreation agencies in Illinois as well as across the country have been leaders in addressing public issues, such as waterfront revitalization. By focusing on such an important issue, the agencies are not only meeting rapidly expanding water-related recreational needs but are also assisting communities by transforming a resource, which in many cases has been a detriment to a community, into a vibrant and vital economic attraction.

In northeastern Illinois, this rebirth has occurred along the Chicago River, where beautification efforts in the downtown area by the Chicago Park District have provided the impetus for rapidly expanding private development. The quality of water in the river has so improved that people fish in the river again and several rowing regattas are held on it each year.

Another success story in waterfront revitalization has occurred along the Fox River in Kane County, where the Kane County Forest Preserve District and park districts in Aurora, Batavia, Geneva, St.Charles, and Elgin have cooperated to preserve and protect the shoreline and the flood plain. They have also worked in concert with private enterprise to create a new image for the Fox, one that affords beauty, enjoyment, and space for recreation. This new image contrasts with the mills, industrial wastes, and poor water quality of the past. Recreationists can hike, bike, or canoe the length of the Fox in Kane County and stop for pleasant interludes at restaurants, small shops, cultural features, or parks along the way. Not only is this section of the Fox River providing outstanding recreation for local residents, but it is also attracting tourism and therefore is providing a significant economic return to the area.

Preserving aquifers. In 1913 the Illinois Legislature created the Forest Preserve District Act. But in 1963, the power of the forest preserve districts was broadened to enable, among other things, the acquisition of "lands . . . along or encircling watercourses, drainageways, lakes, ponds, planned impoundments or elsewhere which . . . are required to store floodwaters or control other drainage and water conditions necessary for the preservation" of the aquifers that hold our fresh water supply reserve underground. The revision of the act also

Chicago skyscrapers look down on this peaceful lagoon in Lincoln Park.

provided for expanded taxing and bonding powers for these districts, which resulted in a rapid acquisition program as well as comprehensive and innovative approaches to addressing public policy issues including flood control, wetland preservation, solid waste disposal, and mineral extraction.

The DuPage and Lake County Forest Preserve districts in the Chicago metropolitan area have been the leaders in developing innovative programs to meet broader community needs than recreation, nature education, and open-space preservation. By acquiring "environmental corridors" along most of their primary river systems, these districts have reduced the adverse economic impact of flooding in subdivisions; they have restored thousands of acres of wetlands that provide aquifer recharge areas and improved habitat for wildlife; they have used solid waste to create sanitary landfill hills that are being used for recreation; and they have selectively removed scarce sand and gravel deposits to supply businesses using these critical minerals in the urban area while creating water bodies for fishing and recreation.

The 30,000 acres controlled by these districts are open to the public for a wide variety of educational and recreational uses. Just the preservation of this much open space in such a highly urbanized area is a tribute to the extraordinary efforts of the policy boards and professional staffs of these public agencies.

Many park and recreation agencies provide excellent cultural facilities and opportunities ranging from ethnic festivals to zoos. The Chicago Park District, for example, cooperates with private nonprofit organizations to operate their outstanding botanical gardens north of the city and Brookfield and Lincoln Park zoos within it.

Zoos and aquariums. Throughout the world, zoos, or zoological gardens as they are sometimes called, are among the most popular facilities provided in municipalities directly or through a park and recreation agency. Using attendance figures from member institutions, the American Association of Zoological Parks and Aquariums (AAZPA) estimates that more Americans visit zoos and aquariums than all major sporting events combined. In 1983, for instance, five Illinois zoos and one aquarium reported an attendance of 8,070,520. Illinois AAZPA members are Miller Park Zoo (Bloomington), Chicago Zoological Park (Brookfield), Lincoln Park Zoo, Glen Oak Zoo (Peoria), Henson-Robinson Zoo (Springfield), and the Shedd Aquarium.

Early zoos were menageries — mere collections of strange beasts and birds kept in sterile iron-bar cages. Scientific study was conducted mainly on comparative anatomy and taxonomy and to a lesser extent on pathology. The supply of specimens seemed endless, and reproduction within zoos was given little attention. This situation changed after World War II although the warning signs had existed for some time. For example, the passenger pigeon and Carolina parakeet both bred readily in zoos but were not managed for reproduction. When their natural populations died out, it was too late: the last surviving specimen of each died in the Cincinnati Zoo in 1914.

Islands of conservation. Modern zoos are islands of conservation and education that are actively engaged in a variety of research designed to protect and propagate animals whose existence in the wild is threatened. Many zoos have abandoned the Noah's Ark concept of exhibiting two of everything in order to specialize in certain species and build up herds and flocks of them. Research today encompasses reproductive physiology, nutrition, behavior, and comparative pathology — to name a few. Great expense has been incurred to replace iron-barred cubicles with safe, natural-looking habitats, which are not merely appealing to the zoo visitor but, more importantly, are conducive to the normal behavior and reproduction of the animals.

There are species of animals today that survive only in zoos, such as Przewalski's horse, Père David's deer, the red wolf, the Amoy tiger, and the

Over two million school children and adults come each year to see how farm animals are fed and cared for at the Lincoln Park Farm-In-The-Zoo in Chicago. All of the exhibit buildings on this five-acre tract show farm animals in their natural surroundings and are accurate replications of farm life.

European bison (or wisent). Some species have been reintroduced into the wild after having become extinct or nearly so in their native habitats. These include the Arabian oryx, American bison, golden lion marmoset, and the state bird of Hawaii, the nene goose. There are also several species whose zoo populations exceed the natural and whose reintroduction is planned: the black rhinoceros, the addax, Rothchild's mynah, the Indian lion, and scimitar-horned oryx.

Databases for propagation and health care. Inbreeding exotic species is similar to inbreeding domestic animals in that it amplifies genetic weaknesses. To help prevent the harmful effects of inbreeding, gene pools are being identified for zoo animals all over the world. In 1975 the International Species Inventory System (ISIS) was established. Currently housed at the Minnesota State Zoo, ISIS electronically records all the information that is known about each animal in AAZPA member zoos, most foreign collections, and private breeding herds. With funding from the American Association of Zoo Veterinarians, ISIS also has established normal laboratory data for hundreds of species. This information is invaluable to the veterinarian trying to determine the cause or extent of an animal's illness and could include answers to questions like what is the normal white blood cell count of a gorilla. In 1981 the Species Survival Plan (SSP) was devised by AAZPA for endangered and threatened species. Using ISIS information and computer-generated programs, SSP formulates breeding plans for captive specimens to broaden their gene pools and ensure healthy offspring.

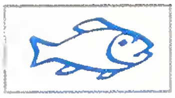
Modern technology has been applied to propagation as well. Electro-ejaculation has been performed in most zoo species. The freezing of embryos and semen has been successful, and the "frozen zoo" is literally on the horizon. Embryo transfer from exotic donors to domestic recipients has been accomplished, for instance, from a zebra to a quarterhorse in Louisville and from a gaur to a Holstein at the Bronx zoo. Illinois zoos have been active in this research and have received seven prestigious E. H. Bean awards for propagation of zoo animals. Brookfield has received five, and the Lincoln Park Zoo has received two of these awards.

The next time you engage in America's favorite sport of zoo-going, remember that zoos are doing much more than just displaying these wonderous animals in pleasant surroundings. Consider a zoo a bit like a swan on a pond — beautiful and serene on top, but paddling like mad below.

Robert D. Espeseth, associate professor of recreation, and Thomas J. Burke, associate professor of veterinary clinical medicine

Places To See

The Illinois and Michigan Canal National Heritage Corridor, a 120-mile historical and environmental corridor from Chicago to LaSalle-Peru, is the only site in Illinois besides the Lincoln Home in Springfield that is a part of the National Park System. Built between 1836 and 1848, the Canal played a significant role in the history of Illinois. As the newest member of the National Park System, it will provide opportunities for hiking, canoeing, fishing, camping, snowmobiling, and cross-country skiing.

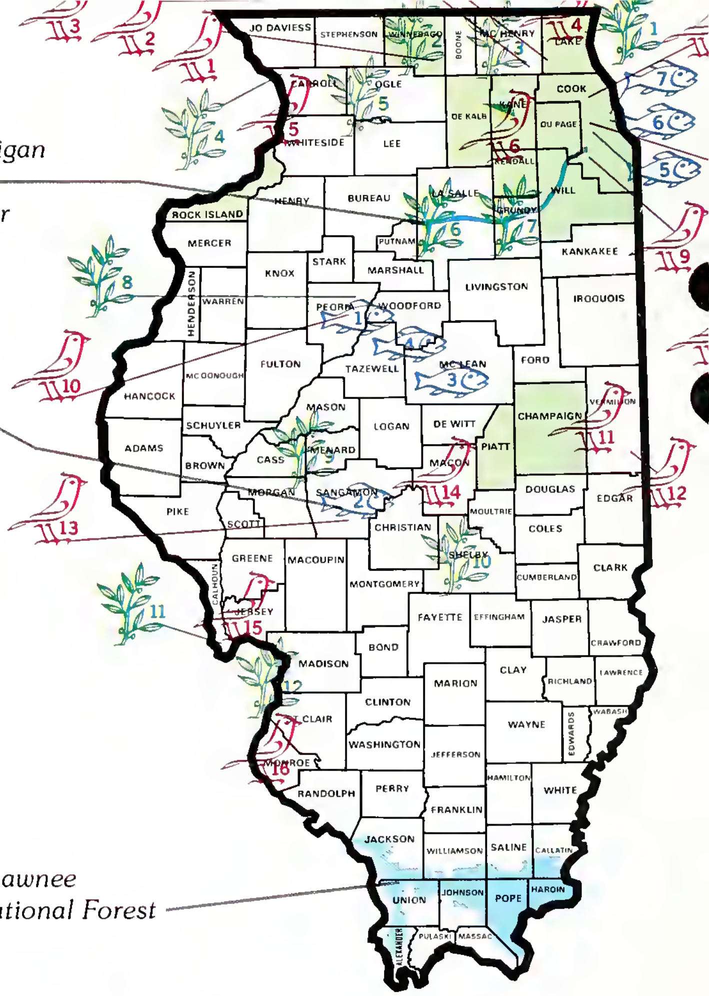


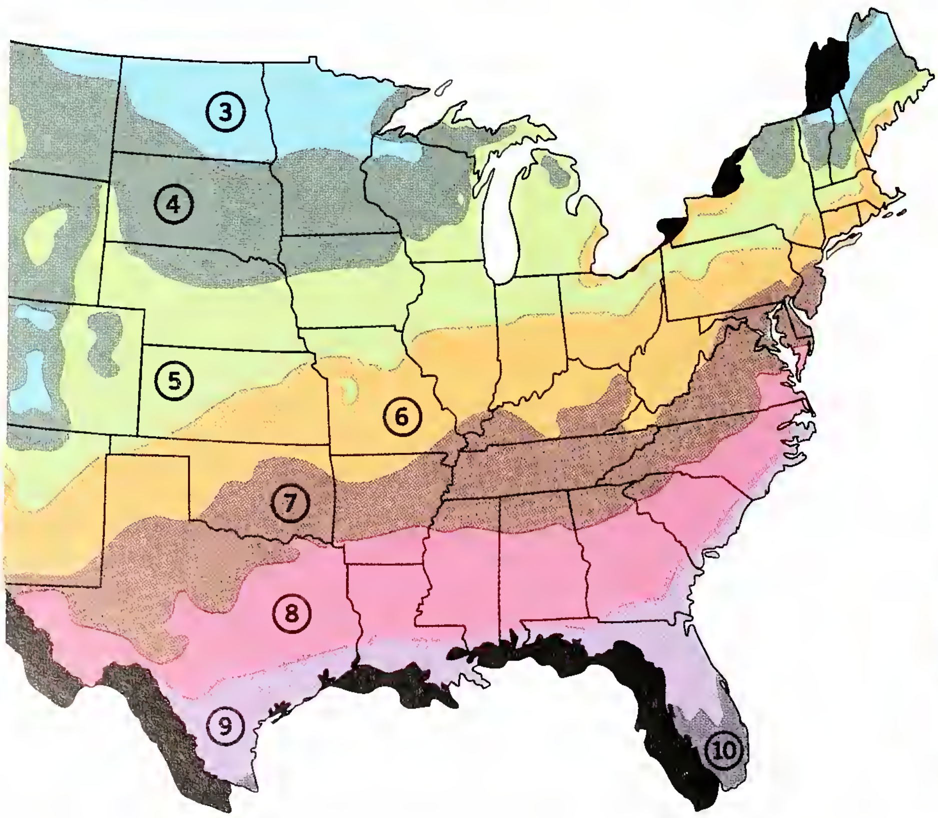
Zoos and Aquarium

Illinois has many excellent zoos and an aquarium that are worth visiting:

1. Glen Oak Zoo, Peoria
2. Henson-Robinson Zoo, Springfield
3. Miller Park Zoo, Bloomington
4. Timberedge Farm, Goodfield
5. Chicago Zoological Park, Brookfield
6. John G. Shedd Aquarium, Chicago
7. Lincoln Park Zoological Gardens, Chicago

Counties with a forest preserve district





Hardiness Zone Map

Hardiness is the ability of a plant to thrive in a particular environment. The zone map here has been adapted from the map issued by the U.S. Department of Agriculture. Each zone represents an area of winter hardiness based upon minimum winter temperatures, ranging from -50° F (-46° C) or below in Zone 1 to 40° F (4° C) in Zone 10. A plant is usually listed in the coldest zone in which it will grow normally. You can use this map to check the suitability of a climate for the grasses described on pages 8 and 9.

Range of Average Annual Minimum Temperatures

Zone 3	(− 40° to − 30°)
Zone 4	(− 30° to − 20°)
Zone 5	(− 20° to − 10°)
Zone 6	(− 10° to 0°)
Zone 7	(− 0° to + 10°)
Zone 8	(+ 10° to + 20°)
Zone 9	(+ 20° to + 30°)
Zone 10	(+ 30° to + 40°)

Preserves and Parks

Illinois has over 140 nature preserves and over 70 state parks. Many of these and numerous city parks are easily accessible to urban populations. The map shows only a few of the more noteworthy accessible parks. For more information about the preserves and parks near your community, call the Illinois Nature Preserves Commission, (217) 785-8686; the Illinois Department of Conservation, (217) 782-6752; or your regional office of the Department of Conservation:

Region I	Sterling (815) 625-2968
Region II	Spring Grove (815) 675-2385
Region III	Champaign (217) 333-5773
Region IV	Alton (618) 462-1181
Region V	Benton (618) 435-8138
Chicago (312) 793-2071	

Adapted from *The Natural Resources of Illinois: Introduction and Guide*, Illinois Natural History Survey Special Publication Number 6, by R. D. Neely and C. G. Heister, Champaign.

Nature Preserves

1. Rockton
2. Kettle Moraine
3. Volo Bog
4. Illinois Beach
5. Thomson-Fulton Sand Prairie
6. Nelson Lake Marsh
7. Morton Grove Prairie
8. Salt Creek Woods
9. Black Partridge Woods
10. Forest Park
11. Middlefork Woods
12. Russell M. Duffin
13. Carpenter Park
14. Bois du Sangamon
15. Père Marquette
16. Fults Hill Prairie

State Parks

1. Illinois Beach*
2. Rock Cut*
3. Moraine Hills*
4. Mississippi Palisades*
5. White Pines Forest*
6. Starved Rock*
7. Goose Lake Prairie*
8. Jubilee College*
9. Lincoln's New Salem*
10. Eagle Creek*
11. Père Marquette*
12. Cahokia Mounds

* Recreational areas that in some way have been made accessible to the handicapped. For information about these and other parks, call the Illinois Department of Conservation or your regional conservation office.

Embryo transfer — in this case from a zebra to a quarterhorse — is just one technique modern zoos use to ensure the propagation of exotic species. Other techniques are described on pages 12 and 13.

Scenic trails like this one in the Kane County Forest Preserve District abound in the eleven active county Forest Preserve districts of Illinois: Champaign, Cook, DeKalb, DuPage, Kane, Kendall, Lake, Piatt, Rock Island, Will, and Winnebago.

Therapeutic Value of Plants

James E. Schuster

In DuPage County, as in many other areas throughout the United States, seniors are the fastest growing segment of the population. Of the 4,500 seniors who live in DuPage County, which is located about 15 miles west of Chicago, over 1,400 live in one of 28 nursing or retirement homes. Within several of these facilities, one technique that staff members try to adapt to the patients' wide range of abilities is horticulture therapy. Basically, the purpose of horticulture therapy is to help improve the individual's mental, physical, or social activity — or a combination of the three.

Depending on the season, about one-tenth of the residents participate in horticulture programs. Because most residents are not able or willing to garden at temperatures in the sixties or lower, vegetable gardening is scheduled from Memorial Day weekend to Labor Day weekend, to accommodate the health needs of seniors. The other nine months are devoted to growing houseplants.

The local Cooperative Extension Service (CES) office has developed a cooperative working arrangement with Cantigny Gardens and the College of DuPage. Cantigny donates numerous flats of annuals for the summer gardening as well a place to grow some vegetable transplants. The College of DuPage offers horticulture classes on houseplants and propagation techniques — and previously discarded the plants produced in these classes. Now, however, the plants are donated to the CES horticulture therapy program.

Results. The impact of this CES horticulture program is hard to define in global terms. But there are many individual successes.

Because of the change in the residents participating in the horticulture therapy program, several homes have marked funds to buy plants, containers, and seeds; put in sidewalks around gardens; and built raised planting beds that are more accessible to the residents. One home is converting a seldom-used roofed patio into a solarium so that even more horticulture therapy can be done year around.

The rates of physical or mental decline of some residents have slowed since the horticulture program began. Other residents have shown vast improvements. In several instances, residents who didn't interact with other residents became active in vegetable gardening or growing houseplants. They started to visit other residents and join in other activities as well. In general, friends and relatives visiting the residents noted an improvement in the quality of their visits because the residents are eager to discuss their latest gardening venture.

James E. Schuster, senior Extension adviser, horticulture, DuPage County

Therapeutic Value of Animals

Joseph Orthoefer

Mildred Arneson and other residents of nursing and children's homes in Champaign-Urbana enjoy receiving weekly pet visits by puppies and kittens. These visits are made possible by the Champaign County Humane Society's Pets-On-Wheels program, which is now under the direction of Arthur Melnick, an associate professor of philosophy at the University of Illinois at Urbana-Champaign.
Photograph by David Riecks

"For millions of years we have lived in common with the rest of the natural world, and in those millions of years, we have evolved genetically to live in harmony with it. This harmony resulted in symbiosis, a relationship whereby each species helps each other, but each is able to survive separately. We evolved to live symbiotically with other animals," according to Bruce Fogle in *Pets and Their People*.

Humans domesticated dogs twelve thousand years ago, and cats five thousand years ago. Dogs were domesticated first as hunters and then as providers of safety and companionship; and cats not only controlled rodents but also provided companionship. Today pets are used somewhat for the same purposes, with the qualification that the human-animal bond has become much stronger in an emotional sense. Now, pets are used as companions and helpers and, most recently, in therapy.

It is not surprising that therapists are now including pets in organized therapeutic programs. There is every indication that pets increase sociability, decrease heart rate in anxiety-provoking situations, possibly extend the survival time of coronary victims, and reduce the isolation of autistic children. In fact, *Newsweek* magazine recently reported that more than one thousand hospitals and other institutions now use pets in a form of therapy.

The reports coming from many institutions have heightened an awareness of the value of animals in therapy programs. Animal shelters can, with little effort and the use of volunteers, improve upon their image as the "dog pound" and the "dogcatcher." The workers at the institutions are grateful, and the people served often have their lives improved by the use of animals in therapy programs.

Interviews with pet owners have indicated that pets are extremely important when people are lonely, depressed, or ill. Some surveys have indicated that as many as 80 percent said stroking a pet helped them relax, 50 percent indicated they felt safer, and 27 percent indicated pets helped them make friends.

Aaron Katchen at the University of Pennsylvania lists seven benefits that pets can give humans: companionship, something to care for, something to keep a person busy, something to touch and fondle warmly, something to watch, something that makes one feel safer, and something that provides a stimulus for socialization.

In Winnebago County we have, on a number of occasions, used selected animals from the shelter for nursing home visits and for vists to institutions for the developmentally disabled. To date, our experiences have been good. On one of our visits, a dog sparked the interest of a child who had not talked in months. She made the statement, "I don't like cats," and repeated it the next visit.

Through this program we are finding that the use of animals as a tool in therapy, although apparently very useful, is not the only benefit. We hope to find that animals used with the developmentally disabled will become a very efficient teaching tool. We reason that when patients who have been taken care of all their lives are then given the responsibility of caring for another living thing, it can help them better learn to care for themselves.

To facilitate the use of animals in various institutions, an agreement is written with each facility to specify:

- How often animals will be taken to the facility.
- Conditions under which the clients can interact with the animals.
- Additional procedures, such as the formation of interest clubs.
- What type of animals will be taken to the facility.
- Provisions for those who do not care for animal contact.

We plan to document the methods that are used so we can continously improve the results of the program. For those of us at Animal Control, outcomes are viewed from two perspectives: the residents of the facilities visited benefit, and we are provided the opportunity to research pet-facilitated therapy as intensively as possible.

Joseph Orthoefer, D.V.M., administrator, Winnebago County Department of Public Health, Rockford, Illinois

Companion Animal Health

Allan J. Paul

Dramatic advances have been made in veterinary medicine in the past twenty years. The scope and technology of veterinary care for our companion animals are now comparable to those of medical care for humans: many once fatal diseases and conditions are now preventable or treatable, and advances in health care allow our pets to enjoy longer and healthier lives.

Increasingly, people have begun to recognize the importance of the bond between themselves and animals and the value of pets. As more and more pets become members of their families, people have come to expect high-quality health care for them. Pacemakers, kidney dialysis, total hip replacements, cancer therapy — almost anything in human medicine is now available to pets.

Many serious diseases of dogs and cats are now easily prevented because of the availability of safe and effective vaccines. Two recent advances in this area are vaccines against canine parvovirus and feline leukemia. Canine parvovirus is a potentially fatal disease of dogs that first appeared in the late 1970s and rapidly spread throughout the United States. Fortunately, cooperative research efforts led to the rapid development of effective vaccines that have reduced the incidence of the disease. Another major breakthrough has occurred with the development of a vaccine against feline leukemia. This contagious viral disease manifests itself as cancer or as immune-deficiency-related problems in cats and eventually results in death.

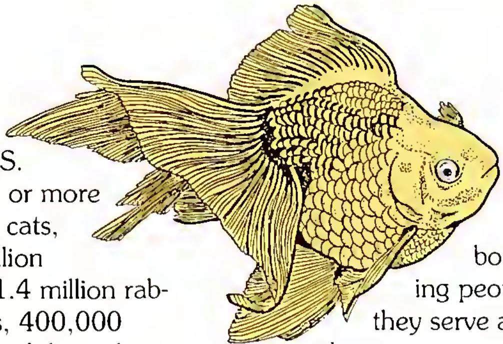
Many advances in companion animal health care have not only benefited our pets but have also improved human health. The findings from research on animal diseases are often applied to medical research on humans. A good example of this collaborative research has been the development of the Illinois Comparative Oncology Program (ICOP) at the University of Illinois. The ICOP joins veterinarians at the College of Veterinary Medicine with researchers in other units across campus. Members of the group are currently investigating several drugs that can be used for cancer treatment. They are also evaluating a new machine that kills cancer by ultrasound-transmitted heat. Unlike the machines used in previous methods of hyperthermia (heat treatment), this machine can even heat irregularly shaped tumors without burning surrounding tissues. Because heat also makes drugs more effective at a lower dose, ICOP researchers plan to investigate how much they can lower drug dosages as they apply levels of heat. Hopefully, their findings will eventually help both human and animal cancer patients.

Many advances have been made in companion animal health care that have greatly improved the quality of life and lengthened the lives of our pets. Continued research efforts, it is hoped, will advance both companion animal and human health care.

Allan J. Paul, assistant professor, small animal Extension veterinarian ☐

Companion Animals in the Urban Environment: More Than Mere Pets

Gail L. Czarnecki-Maulden and Laurie M. Lawrence



Eighty percent of all U.S. households include one or more pets. About 51 million cats, 50 million dogs, 20 million fish, 4.2 million birds, 1.4 million rabbits, 600,000 hamsters, 400,000 guinea pigs, 400,000 gerbils, and 400,000 reptiles are kept as pets in the United States. Between 28 and 34 percent of these households own cats, with an average of two cats per household; and between 38 and 52 percent own one or two dogs. About 80 percent of the 8.2 million horses in the United States are maintained for hobby and recreational use; 28 million people ride horses each year. These and other companion animals serve people in many ways.

Recent research has shown that owning a pet can improve a person's physical and mental well-being. As a result, many programs have been developed to use pets in therapy for emotionally disturbed children, criminally insane prisoners, and elderly people in nursing homes. Horseback riding programs for the physically and mentally handicapped, for instance, are becoming increasingly common, and a program has been started in at least one state to teach prisoners about racehorse management in order to provide them with skills that are marketable after their release. In addition to their use in therapy and their traditional roles as guardians and hunters, dogs have been trained to guide the blind, hear for the deaf, aid the handicapped, and locate drugs, bombs, and missing people. Because they serve as much more than mere pets, companion animals are numerous and have a significant impact on our economy.

Dogs and cats. Dogs and cats are a vital part of the economy. Owners spend $5 billion each year on veterinary services. In 1986, sales of 9.3 billion pounds of dog and cat foods reached $5.2 billion. These sales represent a 329 percent increase in dollar-volume since 1970. By comparison, the poultry industry spends about $5 billion, and the swine industry about $1.5 billion a year on feed. The manufacture of these pet foods, therefore, is one of the most rapidly growing areas of the animal feed industry. Each year, in fact, over 1.5 billion tons of soybean meal is incorporated into pet foods. Nevertheless, relatively little is known about the nutritional requirements of cats and dogs or about the factors affecting these requirements.

Because of the great number of dogs and cats in our homes and their economic importance, the College of Agriculture at the University of Illinois recognized the need for excellent nutritional research on these species. With the initiation in 1973 of a research and teaching program on canine and feline nutrition and management, it became the only college of agriculture in the United States to have such a program. Researchers in the Department of Animal Sciences at this university have subsequently made many important discoveries about canine and feline nutrition. Their research has centered on determining the nutritional requirements and understanding the metabolic processes of these species. Requirement estimates for all of the essential amino acids in the dog, many of the essential amino acids in the cat, iron in both the cat and dog, and magnesium in the cat were discovered at the University of Illinois. Current research is directed at estimating the requirements for the remaining minerals, examining the availability of amino acids and minerals in practical feed ingredients, and determining the effects of food processing on the availability of nutrients. This research has practical implications not only for dogs and cats but also for humans consuming processed foods.

Studies conducted primarily at the University of Illinois and at the University of California at Davis have uncovered a number of nutritional idiosyncrasies of cats. Many of these metaboic peculiarities and unusual dietary requirements may be related to the adherence of the cat to a strictly carnivorous diet. Some of these anomalies are of purely scientific interest; others have practical importance.

Cats are the only species of animal known to require the amino acid taurine, which is found in high concentration in the eye. Although the exact function of taurine is unknown, taurine deficiency causes the retina of the eye to degenerate and eventually results in blindness. Most species can synthesize adequate quantities of this amino acid to meet their needs. Cats are not only inefficient at sythesizing taurine, but they also have a higher physiological need than other mammals. Found only in animal products, it is one of the most critical of all the nutritional idiosyn-

crasies of the cat. Cat owners who try to cut expenses by feeding dry dog food to their cats are probably providing a taurine-deficient diet because most dry dog food is primarily composed of plant products. These cost-conscious owners, moreover, often do not notice this deficiency until irreversible blindness has occurred because the retinal damage develops slowly over several months or years.

A second nutrient that is found only in animal tissues and is specifically required by the cat but not other mammalian species is arachidonic acid. Cats cannot synthesize this fatty acid. Mineralization of the kidneys is one sign of arachidonic acid deficiency. Fish oil is the richest source of arachidonic acid; turkey and beef fat also contain appreciable quantities; but vegetable fats, such as corn oil and vegetable oil, contain none at all.

Other nutritional idiosyncrasies of cats that could pose problems are their high protein requirement and their sensitivity to excessive amounts of magnesium. Cats require more protein than any other species of animal and poorly adapt to changes in the quantity they consume. Most commercially available dry dog foods lack the amount of protein that cats need. Dry dog foods and other vegetable-based diets also contribute to high urinary pH. Feline Urologic Syndrome (FUS), one of the most common health problems of cats, occurs in cats that consume excessive amounts of magnesium under conditions of high urinary pH. FUS is characterized by the formation of urinary calculi (stones).

Cats also respond more severely than other species to an arginine-free diet. Arginine is an amino acid that helps the body rid itself of excess nitrogen. Consumption of as little as one meal containing no arginine can elevate the level of a cat's blood ammonia and cause vomiting, convulsions, and even death. Commercial cat food is not deficient in arginine.

Many of the nutritional idiosyncrasies of cats may lead one to conclude that they should only be fed meat. This conclusion is a dangerous assumption. Meat is deficient in a number of amino acids, vitamins, and minerals, and it has a grossly imbalanced ratio of calcium to phosphorus. The ratio of Ca:P in meat is about 1:20; the proper ratio is 1:1. It is important to remember that the ancestors of our domestic felines consumed not only the skeletal muscle and vital organs of their prey, but also the bones, stomach, and intestinal contents.

Horses. The status of the horse has changed dramatically over the last fifty years: no longer generally needed for work or transportation, the horse is used predominantly for entertainment, recreation, and companionship by millions of people in Illinois alone. Attendance at Illinois racetracks, for example, exceeds five million, while numerous horse shows and other horse events entertain thousands more. The large horse industry and good facilities make Illinois the home of a number of world-class horses and riders; and many national and international horse competitions are held in Illinois each year. Illinois residents enjoy not only watching but also riding horses: over 400,000 ride regularly. Because of the great number of horses in urban and suburban settings in this state, 4-H projects with horses are almost as numerous as projects with swine — the leading Illinois livestock specie. Illinois youth participate in other structured horse activities through the United States Pony Club, Future Farmers of America, the American Horse Association, the American Quarter Horse Association, and many other organizations. For many people, horse ownership and participation in the many breed organizations, saddle clubs, and other groups clearly afford opportunities for social interaction as well as physical activity. Therapeutic riding programs have been developed in many areas of the state for physically handicapped, mentally retarded, and emotionally disturbed children and adults. Because owning and riding horses satisfy so many needs of the people of Illinois, the horse industry continues to have a significant impact on its economy.

Illinois ranks in the top five states nationally for the number of horses in the state. Estimates range between 270,000 and 300,000 horses. The state horse population consumes at least 1 million tons of feed each year. An estimated $450 million is spent on

horse care in Illinois annually. A report from the Governor's Task Force on Racing (1985) indicates that there are 1,500 breeding farms in Illinois. These farms generate direct or indirect employment for at least 40,000 people. Racetracks also employ many people, particularly urban dwellers. In addition to income and employment, the horse industry generates direct revenue for the state through income, sales, and property taxes. In *Western Horseman* (June 1982, p. 111), Burke estimated that over $150 million was paid to the state by horse owners in 1982. Taxes on pari-mutuel betting alone amount to more than $50 million annually. Used to fund facilities at fairs and expositions and to support the Illinois Agricultural Premium Fund, these taxes benefit people in urban as well as rural areas all across the state.

Given the importance of this companion animal in the lives of Illinoisans, the College of Agriculture has always been committed to serving the interests of the Illinois horse industry. At the peak of the draft horse days, the Department of Animal Sciences published numerous bulletins based on research on its excellent Percheron horses. When draft horses were replaced on the farm by tractors, they were replaced at the University of Illinois by American Quarter Horses. Pursuit of excellence in equine research, teaching, and extension has continued to the present day.

Since 1981, over forty papers relating to horse research have been presented by researchers in the Department of Animal Sciences at national and international scientific meetings. Research areas have included nutrition, reproductive physiology, growth, and exercise physiology.

Because a large portion of a horse's diet is roughage, studies have been conducted to evaluate the sources of roughage. Humid Illinois summers, for example, often complicate the making of good hay. Hay that is baled with a high moisture content will become moldy during storage, and moldy hay is unsuitable for horses. Chemical preservatives that can reduce or prevent molding of hay are available, but their effect on the palatability of hay was undetermined until recently. A University of Illinois study revealed that horses consume preservative-treated hay at the same rate as untreated hay and that horses on a preservative-treated hay diet gained weight like horses on an untreated hay diet. In other studies, alfalfa haylage was found to be an acceptable feed for broodmares and growing horses. Ensiling alfalfa can improve the quality of the feed and allows storage of roughage at a higher moisture level than hay does. These studies and those on treated hay have been of interest to horse owners and forage growers because they provide new options for feeding horses.

Other studies have been aimed at understanding the important metabolic processes that occur during exercise and developing diets for optimal performance and growth. Nitrogen metabolism during exercise has been of special interest. One finding, the increase of blood ammonia levels during exercise, may be particularly significant. Hyperammonemia may have toxic effects. Moreover, ammonia or some of the compounds involved in the pathway that releases ammonia, may be involved in regulating cellular energy metabolism.

The effect of dietary protein level on the production of ammonia during exercise and the effect of ammonia buildup on fatigability are currently being investigated. Evaluating the nutrient requirements of exercising horses will directly affect horses involved in competitive events and may also affect human athletes. The differences as well as the similarities between horses and humans make horses an excellent model for performance studies. Horses use the same biochemical and physiologic systems during exercise as do humans but have a greater work capacity. Horses, moreover, have been selected and bred for ability in specialized activities. Understanding the factors that make the horse a great athlete may unlock the secrets to maximizing human performance as well.

In addition to research, the Department of Animal Sciences serves the horse industry in Illinois through teaching and Cooperative Extension activities. Programs involving pleasure, race, and draft horses reach several thousand people — adults as well as youth.

Gail L. Czarnecki-Maulden and Laurie M. Lawrence, assistant professors, Department of Animal Sciences

Integrated Pest Management in the Urban Environment

Fredric D. Miller, Malcolm C. Shurtleff, and *Philip L. Nixon*

The adult sod webworm, *Pediasia trisecta.*

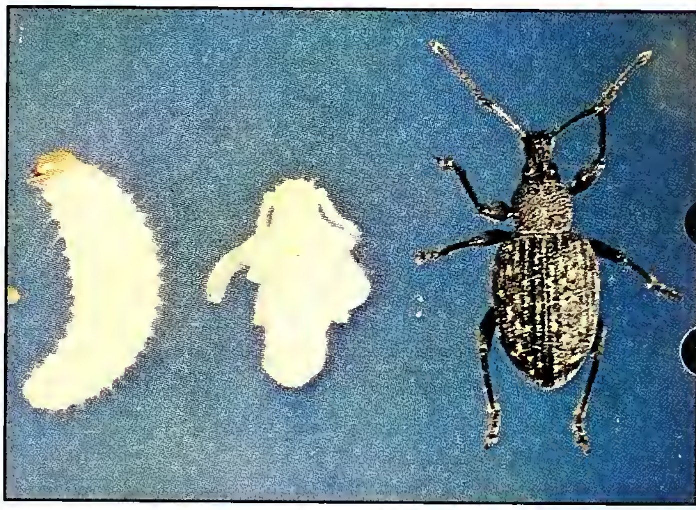
Urban areas provide an atypical environment for most animals and plants. For instance, since 1983, J. H. Witham and J. M. Jones with the Wildlife Section of the Illinois Natural History Survey (INHS) have been studying the white-tailed deer in highly urbanized northeastern Illinois. Large numbers of deer inhabit county-owned forest preserves amid extensive suburban development. During the past fifteen years, reports have increased substantially of deer-related damage both to private property from browsing on ornamental plantings and from accidents with motor vehicles and to county property from over-browsing on understory forest vegetation. Attempts are being made to repel deer in cities.

Although deer are usually not considered a major pest in urban areas, other mammals, insects, weeds, and diseases can be. These organisms can compete with people for a valuable resource or directly threaten their health. To combat them, integrated pest management (IPM) techniques continue to be developed because strictly relying on chemicals for pest control can lead to pest resistance, pest resurgence, and possible harmful effects to humans and to the environment.

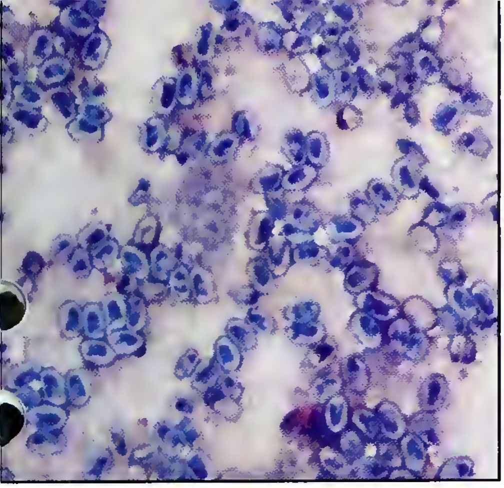
Integrated pest management is the use of appropriate control measures that reduce pest populations to acceptable levels while minimizing their detrimental human and environmental effects. IPM may include the use of cultural practices: crop rotation with unrelated plants, use of disease-free seed and other planting materials, proper sanitation, soil preparation, planting, mulching, watering, pruning, fertilization, control of insect vectors and weed hosts, and winter protection. Mechanical/physical control (barriers, fly swatters, and temperature), resistant and tolerant plant varieties, biological control (parasites, predators, and pathogens), and chemicals may also be part of IPM.

Employing insect pathogens. Naturally occurring insect pathogens are one element of an integrated approach to pest management that has received the attention of J. V. Maddox, insect pathologist at the Illinois Natural History Survey and at the University of Illinois, and others across the nation. One group of pathogenic organisms, microsporidia, is being studied particularly as it affects sod webworm populations in east central Illinois. Sod webworms are a common pest of commercial and residential bluegrass turf. Their larvae feed on grass blades, clipping them right at the base or crown of the plant. The microsporidia infect the young larvae and eventually cause death. This pathogen is transmitted from generation to generation by the egg. Within a generation, transmission occurs from larvae to larvae. By examining adult moths, evidence of the disease can be determined. These data will aid entomologists in better understanding the role of microsporidia in sod webworm population dynamics. Studies are also being conducted on how microsporidia affect the overwintering ability of sod webworm larvae. Sod webworm larvae overwinter near the soil surface in cocoons constructed from grass blades and plant

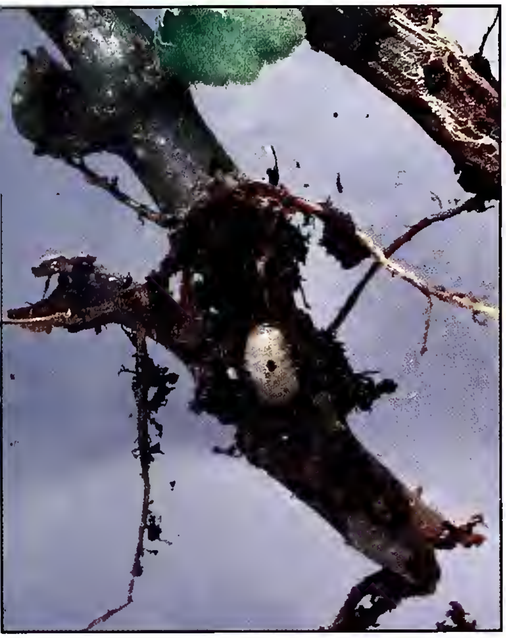
The larva of the sod webworm and the turf-feeding damage it causes.



Larva, pupa, and adult of the black vine weevil, *Otiorhynchus sulcatus.*



A naturally occurring microsporidia, *Nosema* sp., common in sod webworm populations.



Root-feeding damage caused by the larva of the black vine weevil.

debris. Because of their overwintering habits, they can be exposed to severe winter temperatures. Comparing the survival rate of infected and noninfected larvae, it is hoped, will provide information on population levels for the following growing season.

Selecting resistant or tolerant plants. Planting resistant or tolerant plants is another component of IPM that is utilized more and more in the urban environment. By using plant material that is resistant or tolerant to damage caused by insects or pathogens, the dependence on chemicals can be reduced. Specific varieties of ornamental honeysuckle, for instance, are used to prevent or reduce damage by the honeysuckle or "Russian" aphid. This aphid tends to severely attack *Lonicera tatarica* 'Zabelii' and other large shrub honeysuckles. These shrubs are used as living privacy fences, snow fences, and specimen landscape shrubs throughout Illinois and the rest of North America.

First noticed in northeastern Illinois in 1979, this aphid causes damage by sucking sap from the young leaves at the top of the plant. The death of these leaves causes additional stems and leaves to be produced that are subsequently killed by the aphids. By the end of the summer, this process results in a twiggy mass of growth containing dead and immature stunted leaves called "witches'-broom." Because these twigs are produced too late in the season to be dormant when winter arrives, the entire "witches'-broom" is dead by spring, so most of the summer's growth is eliminated, and bushes are unable to enlarge. If planted in poor growing situations, these bushes might die.

From 1980 through 1983, Philip Nixon, area Extension adviser in entomology, Carolyn Nixon, assistant Extension horticulturist in DuPage County, and James Schuster, county Extension adviser in horticulture in DuPage County, conducted research on the honeysuckle aphid. Using plant collections at the Morton Arboretum in Lisle, Illinois, they identified five varieties of large shrub honeysuckle that grow well in Illinois and that are not attacked by the aphid. These varieties are now grown and marketed by nurserymen as replacements for Zabelii honeysuckle in new landscape designs. With the cooperation of the Illinois Tollway Authority, insecticides were also tested for control of the aphid in existing honeysuckle plantings. This testing resulted in a control program that includes properly timed applications of an insecticide and pruning to remove overwintering eggs.

Another insect that can be a potential problem, particularly in nurseries and landscape plantings, is the black vine weevil, *Otiorhynchus sulcatus*. Black vine weevil larvae or "grubs" feed on roots, severely pruning them. Adult weevils cut U-shaped feeding notches in the outer leaf margins of Japanese yews *(Taxus* sp.*)*, euonymus, rhododendrons, azaleas, and other woody shrubs. Larval root feeding reduces plant growth and revenue because plants must be grown longer in the nursery in order to achieve proper market size. Homeowners may also encounter reduced plant growth and occasional plant death due to this insect when they try to grow plants in marginal growing situations.

Nixon and Fredric Miller, assistant Extension entomologist, are currently screening insecticides to develop control measures for root-feeding larvae at a nursery in McHenry County near Huntley, Illinois. Plans also include developing a larval root-feeding rating system to determine larval damage more efficiently and accurately and to understand better the relationship between black

Typical U-shaped notches along the outer leaf margins due to feeding by the adult black vine weevil.

vine weevil numbers, associated damage, and growth reduction.

Disrupting growth and reproduction. From time to time, certain insects can become a problem indoors either as a public health problem or as a nuisance. Fleas and cockroaches are two of the most common. Until recently, only conventional insecticides were available for control of these pests; however, two new closely related products have been developed that mimic their natural growth hormone in order to disrupt their normal development. This discovery has important implications because some cockroaches have developed resistance to certain conventional insecticides. Using the insect growth regulator known as hydroprene (trade name: Gencor), insect resistance may be delayed while still attaining effective control. A cockroach nymph exposed to Gencor cannot become a reproducing adult. The chemical controls the number of insects not by killing living insects but by limiting the production of new offspring. Adult cockroaches are not affected and will continue to produce nymphs; only cockroach nymphs are vulnerable. Nymphs that are affected will have twisted or deformed wings after becoming adults.

A similar insect growth regulator product known as methoprene (trade name: Precor) has also been developed for flea control. When a flea larva comes in contact with Precor, the larva grows and pupates but never becomes a biting, reproducing adult. Given that an adult female flea can mother thousands of young fleas in one month, the benefits are obvious. To eliminate both adult fleas and cockroaches, conventional insecticides must be used in conjunction with insect growth regulator products.

Boric acid has proved quite effective against cockroaches as well. Boric acid should be used in out-of-the-way places where regular cleaning is not possible, like wall voids and particularly behind and under stoves, refrigerators, and other large appliances. Boric acid should not get wet and should not be used in open areas where children or pets may be exposed to it. Both the insect growth regulator and boric acid are quite safe but should be used according to label directions. Animal tests have shown that some chemicals are 300 to 1,000 times more toxic than Gencor, but Precor is approved by the World Health Organization (WHO) for use in drinking water. Boric acid has a toxicity level comparable to table salt.

Maintaining good sanitation. Two other control components that must accompany any chemical control program are good sanitation and sealing of cracks and crevices. Many household pests feed on "human" food, so proper food storage and cleanliness are important. Depriving these insects of their food source will prevent the spread of infestations, prevent normal development, and reduce food contamination. Properly caulking and sealing cracks and crevices will prevent entry as well as migration of insects once they are inside the home.

Using biological control. Insects in the yard and garden area can sometimes be controlled biologically. One such approach has been the development of the bacterium *Bacillus thuringiensis* as a microbial insecticide. This bacterium has been formulated into an insecticide but only affects Lepidopteran pests. It is quite effective against vegetable pests on cole crops, such as the imported cabbage worm and the cabbage looper. It is equally effective against a number of tree and shrub defoliating insects, including the eastern tent caterpillar, fall webworm, mimosa webworm, and bagworm. The material is very safe to use and poses no threat to the environment. One disadvantage, however, is that it is sensitive to sunlight and usually breaks down in five to seven days. *B. thuringiensis* must be ingested in order to be effective, so it should be applied as soon as larval feeding is observed.

Another strain of this bacterium, *B. thuringiensis*, variety *israelensis*, is an effective insecticide against mosquito and blackfly larvae. This product can be easily applied to small water bodies, such as lagoons and ponds. *B. israelensis* is not harmful to fish or to other aquatic organisms and is quite safe to use.

Herbs are often planted near garden vegetables in an attempt to repel insects. But a study conducted at the University of Illinois has shown that this organic gardening technique produced no apparent beneficial effects. Vegetables, such as cabbage, eggplant, and snapbeans, were interplanted with hyssop, thyme, catnip, wormwood, rosemary, petunia, and marigold. In all cases, the herbs did not reduce insect pest populations or insect feeding damage. The herb plants apparently did not mask the attractant of the host

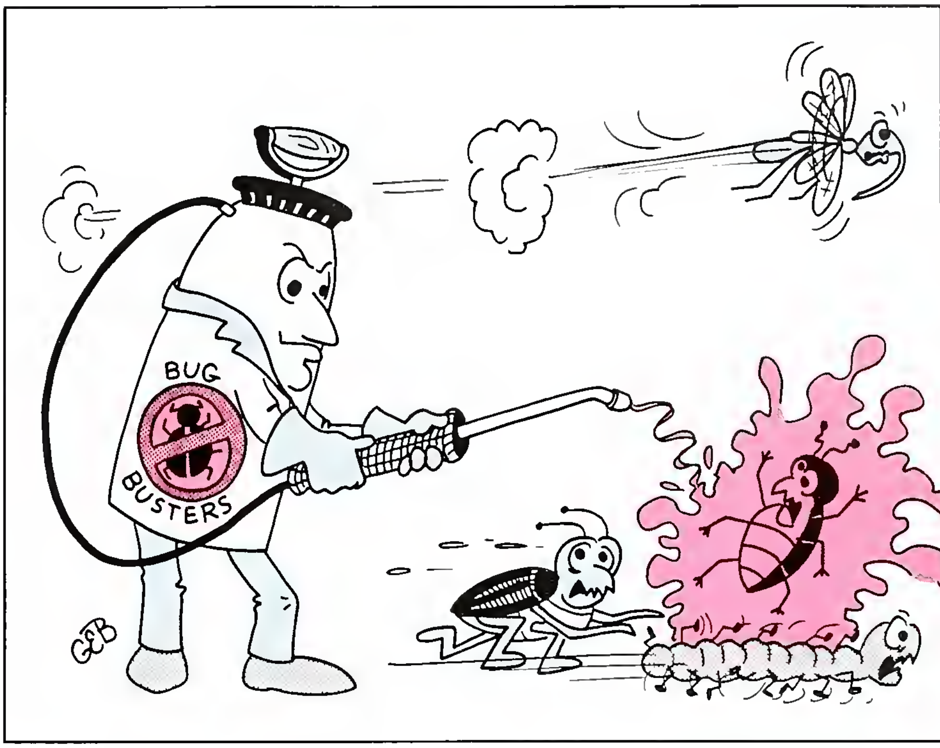
vegetables, nor did they repel the insects studied.

Applying pesticides. Not only insects but also plant pathogens can be a problem in the urban environment. Sometimes pesticides may play an important role in controlling the plant diseases caused by these pathogens. Plant disease-control chemicals used inside or outside the home environment, for instance, may include fungicides, bactericides, and nematicides.

Fungicides. Fungicides are used to protect fruits, vegetables, turfgrasses, and both herbaceous and woody ornamentals. The most commonly used fungicides include: captan as protective foliar sprays on fruits and herbaceous ornamentals and as a seed protectant for vegetables, flowers, and turfgrasses; maneb, mancozeb, and chlorothalonil sprays on vegetables and to a lesser extent on fruits, herbaceous and woody ornamentals, and turfgrasses; and benomyl on all types of plants. Fungicide sprays are usually applied on a five- to twenty-one-day schedule to protect susceptible plant parts against fungal leaf spots, blights, blotches, anthracnoses, rusts, flower blights, fruit spots and rots, and mildews. Several other fungicides are often applied to turfgrasses to protect against snow molds, dollar spot, leaf spots and melting-out, summer patch and necrotic ring spot, brown patch, and Pythium blight. These fungicides include anilazine, iprodione, cycloheximide, vinclozolin, mancozeb, thiophanate-methyl, or a mixture of mancozeb and thiophanate-methyl. Most turfgrass fungicides, however, are applied by lawn care personnel and not by homeowners.

Bactericides. The only bactericide that homeowners can buy to control bacterial leaf spots and blights and fire blight of pomaceous plants are copper compounds. Most copper materials do not require a Federal Drug Administration clearance for use as bactericides or fungicides.

Nematicides. The most common nematicides applied to soil in home gardens are metam-sodium (Vapam) and methyl isothiocyanate (Vorlex). These fumigants are applied to soil before planting and control not only nematodes but also fungi, bacteria, many weed seeds, and soil insects.



Many homeowners prefer to apply multipurpose mixes for vegetables, fruits, and flowers. These mixes commonly contain one or more insecticides, a fungicide or two, and often a miticide. The most widely used fungicides in multipurpose mixes include captan, maneb or mancozeb, dinocap, wettable sulfur, and triforine.

Plants that are winter hardy, carefully selected for a particular site, vigorous, and well cared for are relatively free of disease and require fewer applications of disease-control chemicals.

Care in application and cleanup. If used properly in conjunction with other approaches to pest management, pesticides can be very effective and safe, but when used improperly, they can cause possible injury to humans and the environment. When using pesticides in the urban area, a few important points should be remembered. First, make sure the pesticide is labeled and designed to kill the target pest. Second, apply the pesticide according to label directions. Remember, it is illegal to use a pesticide in a manner that is inconsistent with the label. Do not use more pesticide than is prescribed on the label and be sure to wear the proper protective equipment, particularly when mixing the chemical. Third, once the application is complete, be sure to triple rinse all pesticide containers and dispose of them properly. Empty, triple-rinsed pesticide containers should be taken to a sanitary landfill. Other containers, such as aerosol cans, should be wrapped in heavy brown paper and disposed of with the regular garbage. Paper bags should be emptied as thoroughly as possible, wrapped in paper and also disposed of with the regular garbage. Finally, pesticides should be stored in a locked cabinet or locker. ***Never store pesticides in a food or drink container!*** Keep pesticides where they will not be exposed to extremes in temperature and out of direct sunlight. If poisoning occurs, get the victim to a doctor or hospital as soon as possible and take the pesticide label with you!

Fredric D. Miller, Extension entomologist; Malcolm C. Shurtleff, professor of plant pathology; and Philip L. Nixon, area Extension adviser in entomology

For Further Reference

The publications and software listed here provide additional information pertaining to this issue of *Illinois Research.* Some are reference tools; others provide general background information; and still others relate specifically to topics addressed in individual articles.

Publications

Compilation of Statutes Relating to Agriculture and Forestry Research and Extension Activities and Related Matters. H. C. Knoblauch, E. M. Law, and W. P. Meyer. January 1986. Agricultural Research Service, U.S. Department of Agriculture: Washington, D.C. 112 pages.

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Design with Nature. I. L. McHarg. 1969. Natural History Press: Garden City, New York. 198 pages.

The Granite Garden. A. W. Spirn. 1984. Basic Books, Inc.: New York. 334 pages.

Handbook of Pest Control: The Behavior, Life History, and Control of Household Pests. A. Mallis. 1982. Franzak and Foster Company: Cleveland, Ohio. 1,101 pages.

"Lake Michigan's Rebirth Enhances Recreation." R. D. Espeseth. *Illinois Parks and Recreation* (May-June 1984) volume 15, number 3, pages 19 and 29.

"Linear Park Design." R. D. Espeseth. *Park Maintenance* (June 1974) volume 27, number 6, pages 12-16.

"Linear Recreation-ways." R. D. Espeseth." *Parks and Recreation* (April 1976) volume 11, number 4, pages 26-27 and 38-39.

National Forum (Winter 1986) volume 66, number 1, pages 2-40, features several articles on the theme of "Animals in Society," including: "The Human-Animal Bond in the Arts" by C. Harding, "Relationships with Animals: The Impact of Human Culture" by E. A. Lawrence, "Animal-Facilitated Therapy" by M. J. McCulloch, "Animals in Research" by W. J. Dodds, and "Animal Welfare and Animal Rights" by J. L. Albright.

1984 Yearbook of Agriculture: Animal Health — Livestock and Pets. U.S. Government Printing Office: Washington, D.C. 1984-451-734. 646 pages.

Outdoor Recreation in Illinois. Illinois Department of Conservation. 1979. Illinois Department of Conservation: Springfield, Illinois. 254 pages.

Perspectives in Urban Entomology. G. W. Frankie and C. S. Koehler. 1978. Academic Press: New York. 417 pages.

The Pet Connection: Its Influence on Our Health and Quality of Life. R. K. Anderson, B. L. Hart, and L. A. Hart. 1984. Proceedings of Conferences on the Human-Animal Bond (University of Minnesota, June 13-14, 1983 and University of California — Irvine, June 17-18, 1983). University of Minnesota, Center to Study Human-Animal Relationships and Environments: Minneapolis, Minnesota. 456 pages.

"Principles of Plant and Animal Pest Control." *Insect-Pest Management and Control.* Volume 3. 1971. National Academy of Sciences: Washington, D.C. 508 pages.

State Agricultural Experiment Stations: A History of Research Policy and Procedure. H. C. Knoblauch, E. M. Law, and W. P. Meyer. May 1962. Miscellaneous Publication Number 904. U.S. Department of Agriculture: Washington, D.C. 262 pages.

State Park System in Illinois. J. E. Trotter. 1972. University of Chicago: Chicago. 152 pages.

Urban Entomology. W. Eberling. 1975. University of California, Division of Animal Sciences: Berkeley, California. 695 pages.

Over 300 publications and books by specialists at the University of Illinois are available through its **Agricultural Publications Office,** 54 Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801. For a free copy of the catalog, "Publications from the College of Agriculture," which lists the available printed materials and their cost, write to this address. A few of the titles relevant to this issue are listed

Animals

- C 878 From Egg to Chick: A Guide to the Study of Incubation and Embryonic Development
- C 900 Insect Pest Management Guide: Home, Yard, and Garden
- C1034 Feeding Suggestions for Horses
- C1057 Suggestions for Buying and Judging Horses
- C1076 Turfgrass Pest Control
- C1114 Showing, Riding, and Driving Horses and Ponies
- C1125 Beekeeping in the Midwest
- C1137 Destroying Bees and Wasps
- C1149 Dogs and Cats Need Responsible Owners
- C1189 Keep Insect Pests Out of Your House
- SP 52 Principal Parasites of Domestic Animals

Flowers and Trees

- C 883 Chrysanthemums for the Home Garden
- C1033 Pruning Evergreens and Deciduous Trees and Shrubs
- C1061 Tree Damage Around Construction Sites

Garden Talk

This year brings the eleventh season of "Garden Talk," a weekly 2 1/2-minute tv program that is produced and hosted by Sandra Casserly, Extension radio-tv specialist. It features University of Illinois specialists who take Casserly on location to answer questions about vegetables, fruits, flowers, trees, plant diseases, insects, and nutrition. Topics have ranged from budgeting for a garden and checking the safety of home-canned foods to gardening for the handicapped and discovering how tissue culture research improves home-grown fruit.

The program plays on many commercial television stations in and around the state: WCIA, Champaign; WTVO, Rockford; KHQA, Quincy; WTHI, Terre Haute, Indiana; and WPSD, Paducah, Kentucky. The program is also included in "Weekend Gardener," which airs on stations throughout the United States. During each segment of "Garden Talk" viewers are encouraged to contact their county Cooperative Extension Service office for further information.

C1154 Flower Arranging
C1219 Growing Illinois Trees from Seed
SP 68 Flowering Trees for the Midwest

Landscape

C 880 A Simple Rigid Frame Greenhouse for Home Gardeners
C 935 Growing Small Fruits in the Home Garden
C 998 Tree Fruit and Nut Varieties for Illinois Home Orchards
C1013 Growing Tree Fruits in the Home Orchard
C1056 Tips on Picking and Using Strawberries
C1082 Illinois Lawn Care and Establishment
C1102 Nut Growing in Illinois
C1105 Turfgrasses of Illinois
C1111 Landscaping Your Home
C1122 Illinois Fruit Calendar for Growers of Apples, Peaches
C1145 Home Fruit Pest Control
C1262 (SP 56) Illinois Fruit and Vegetable Garden Schedule
NC 26 Lawn Weeds and Their Control
SP 60 Dwarf Shrubs for the Midwest
SP 65 Ground Covers for the Midwest

Fruits and Vegetables

C 884 Growing Vegetable Transplants
C1150 Vegetable Gardening for Illinois
C1241 Vegetable Production Handbook for Fresh Market Growers

Managing Plants

C 817 Plant Breeding as a Hobby
C 844 Hydroponics as a Hobby: Growing Plants Without Soil
C 886 Plant Regulators: Their Use as a Hobby
C1051 Controlling Weeds in the Home Garden
C1259 Plant Disease Control Guide: Flowers and Nonwoody Ornamentals
C1260 Plant Disease Control Guide: Woody Ornamentals
NC 45 Diseases of Tree Fruits

Software

In addition to printed materials, the following computer software has been prepared by specialists and is currently available from **Illinet Software,** 123 Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801:

Evergreen Selection for Landscape Use

Garden Calendar

Shrub Selection for Landscape Use

Tree Selection for Landscape Use

For a complete list of the computer programs that are available through the College of Agriculture, write to IlliNet Software and ask for its free software catalog.

Hatch Act Centennial: 1887-1987

Harvey J. Schweitzer and Donald A. Holt

One-hundred years ago, on March 2, 1887, President Grover Cleveland signed the Hatch Act into law.

Not just another historical fact, this simple statement describes one of the most significant milestones in the development of our country's agriculture and rural economy.

The Hatch Act — named for its chief sponsor, Representative William H. Hatch of Missouri — authorized the establishment of an agricultural experiment station at each state land-grant institution and set up a cooperative system between the stations and the U.S. Department of Agriculture. The Hatch Act was one of a series of extremely important acts passed by Congress over a fifty-five year period that guided the development of American agriculture. Other key legislation included:

- *The Act of May 15, 1862*, which created the U.S. Department of Agriculture.
- *The Morrill Act of 1862*, which established the system of land-grant institutions in each state, with modifications approved in 1880.
- *The Smith-Lever Act of 1914*, which provided for a national agricultural extension system.
- *The Smith-Hughes Vocational Education Act of 1917*, which supported vocational education in agriculture, home economics, and the industries in the public secondary schools.

Today we take for granted our land-grant institution, the University of Illinois, with its College of Agriculture programs in research, teaching, extension, and international studies. Our farmers, rural communities, and urban consumers enjoy the benefits of agricultural research and development in the form of greater efficiencies in plant and animal production, more nutritious foods and reliable food supplies, and improved farm and home management practices. Our educational system of resident instruction and extension programs in agriculture and home economics reaches thousands of individuals, both on the campus and throughout the state. And the benefits of our research and teaching programs extend far beyond our state and national boundaries.

A hundred or more years ago there was no public system for the advancement of agriculture and the improvement of rural life. The "farm problem" was much in evidence and was a deep concern to farmers, state boards of agriculture, agricultural leaders, and agricultural journalists. Abandoned farms, discouraged farmers, dilapidated homes, and demoralized farm families were common subjects for rural commentators. Farmers themselves struggled to better their economic and social lot through numerous reform movements and political actions.

Evolving from these strenuous times and often vigorous public debates came a vision of agricultural science and education addressing the technical, economic, and social concerns of farmers and their families. The land-grant colleges and universities established by the Morrill Act of 1862 were a beginning step in solving the "farm problem." But the development of most of these institutions was slow and painful as states struggled to build faculty and facilities and to shape a new kind of education program — agricultural and industrial education for the common citizen.

The Hatch Act of 1887, according to some historians, provided land-grant institutions with a "second birth" — a rebirth of spirit and purpose. Placing agricultural research programs and, later, extension programs in the same institutions with instructional programs in agriculture, basic sciences, and humanities created a unique and powerful new institutional structure for agriculture. For the first time, universities were linked directly with economic development. In recent years, nations throughout the world have tried to emulate the concept of the land-grant institution.

The Hatch Act was the stimulus needed to initiate research and develop research facilities and programs that would become the foundation upon which successful agricultural teaching and public service programs would be built. Specifically, this act authorized the establishment of a department to be designated as an "agricultural experiment station" at each land-grant institution. The station's general purpose was "to aid in acquiring and diffusing among the people of the United States useful and practical information on subjects connected with agriculture and to promote scientific investigation and experiment respecting the principles and applications of agricultural science."

Federal funds appropriated to each state agricultural experiment station were small — $15,000 annually for "the purpose of paying the necessary expenses of conducting investigations and experiments and printing and distributing the results."

Actually, a number of states, including Illinois, were conducting agricultural research several years before the passage of the Hatch Act. In 1975 we observed the one-hundredth anniversary of the establishment of the the first state agricultural experiment stations.

Our own University of Illinois Morrow Plots were established in 1876, thus making them today the oldest continuously operated research plots in the United States. Although several states had used state funds to support their research before the Hatch Act, that legislation made possible the national and regional system of agricultural experiment stations and research as we know it today.

One year after passage of the Hatch Act, in March 1888, the Illinois Agricultural Experiment Station was established under a nine-member board of

directors appointed by the University of Illinois trustees. As Richard Gordon Moores states in his history of the University of Illinois College of Agriculture, *Fields of Rich Toil*, "the station was considered a department of the University and was housed on the top floor of the chemistry building. A small staff was appointed and about $3,500 of the initial Hatch funds were spent for books and periodicals relating to agriculture, horticulture, botany and chemistry." An upcoming issue of *Illinois Research* will outline the growth of research and many of the important scientific contributions that researchers in the Illinois Agricultural Experiment Station have made over the past one-hundred years.

Since the passage of the Hatch Act of 1887, several other acts have been passed relating to research and education in agriculture and forestry. The Hatch Act as Amended, 1955, stated that "it is further the policy of Congress to promote the efficient production, marketing, distribution, and utilization of products of the farm as essential to the health and welfare of our peoples and to promote a sound and prosperous agriculture and rural life as indispensable to the maintenance of maximum exployment and national prosperity and security. It is also the intent of Congress to assure agriculture a position in research equal to that of industry, which will aid in maintaining an equitable balance between agriculture and other segments of our economy."

The National Agricultural Research, Extension, and Teaching Policy Act of 1985 consolidates policies from similar acts passed in 1977 and 1981. This most recent act adds several new dimensions, as well as reaffirms federal commitments to research on productivity of the food and agricultural system. The act calls for greater coordination of federally supported research, advances in fundamental research, and more effective dissemination of research results to clientele. At the same time, it acknowledges that federal funding levels for agricultural research and extension are not commensurate with the needs of a changing food and agricultural situation in the United States and throughout the world. Several new and expanded federal initiatives are called for, including the following areas:

- Alternatives to technologies based on fossil fuels.
- Human nutrition and food consumption patterns.
- Environmental problems caused by technological changes in food and agricultural production.
- Aquaculture.
- Management and use of the nation's natural and renewable resources.
- Climate, drought, and weather modification.
- The needs of small farmers and their families and the family farm system.
- Expansion of export markets for agricultural commodities.
- More efficient and environmentally sound methods of producing, processing, marketing, and utilizing food and fiber products.
- Expanded programs of animal disease and health care.
- The development of new crops.
- New or improved food processing or value-added food technologies.

The organization and operation of the agricultural experiment station system have become increasingly complex over the years. A dynamic state-federal partnership exists between the individual state experiment stations, the regional associations of experiment station directors, and the Cooperative State Research Service (CSRS) in the U.S. Department of Agriculture. CSRS provides national coordination for the cooperative state-federal research system and serves as a national research-information resource and science-support agency. The four regional associations support a large number of research committees composed of scientists from all areas of agriculture and home economics, representing the member states. State stations, such as our own, support hundreds of research projects with federal and state funds augmented by grant and contract money. Possibly, the word *dynamic* best describes the agricultural research world within which our scientists operate today.

The past and future of U.S. Agricultural research will be highlighted over the course of the next several months, at both the national and state level, through a variety of activities. Two developments at the national level are especially noteworthy. The 1986 USDA Yearbook of Agriculture, titled *Research for Tomorrow*, is devoted to the subject of biotechnology. Also, a 3,300-square-foot exhibit entitled "The Search for Life: Agricultural Science in the Twentieth Century" is being developed through a special grant from the Kellogg Foundation to the University of Maryland. The exhibit will be permanently housed in the Smithsonian Institution in Washington, D.C.

The occasion of the Hatch Act Centennial provides an opportunity to reflect upon the course of history that led to our present agricultural research and education system. It also prompts us to consider the tremendous challenges and opportunities we have in the years ahead. Among other things, the success of the agricultural experiment station system and similar systems in other nations has resulted in bringing world-wide production capacity closer and closer to the effective demand for agricultural products. The next great challenge of the State Agricultural Experiment Station System is to help U.S. farmers compete effectively for a share of the international markets for agricultural products. Promising new developments such as biotechnology and computer technology will play important roles in this competition.

Harvey J. Schweitzer, assistant director, and Donald A. Holt, director, Agricultural Experiment Station

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Illinois Research

Summer/Fall 1987

Illinois Research

Agricultural Experiment Station
Summer/Fall 1987

The Soybean

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 29, Numbers 2/3

To the readers:

Once again, the staff of *Illinois Research* is proud to inform its readers that it is utilizing the most up-to-date information-processing technology to help streamline and improve the production of this quarterly. We are preparing camera-ready copy on our desktops!

In 1986 our graphics director created the charts and graphs of several issues on a Macintosh computer. For the spring 1987 issue, the editors provided IBM WordPerfect text files, which she set in pages using Aldus PageMaker and Quark XPress.

The current issue, however, is the first issue to be completely typeset in house. All the charts, graphs, text, and tables are generated electronically and formatted into XPress pages. Proofs are run on the Apple LaserWriter, and final pages are printed on the Linotronic before illustration overlays are added and the boards are sent to our printer.

Both the editors and the graphics director are delighted with the greater control that desktop publishing offers not only because it will eventually reduce the cost and time involved in production, but also because it allows us to be more creative throughout the entire process.

The editors

The Cover

The soybean, *Glycine max*, is now one of the most important industrial crops of the United States. The whole soybean and the meal and oil of these miraculous seeds are used in a growing number of products, which continue to transform the agriculture and economy of the United States and many countries throughout the world.

Photograph by Paul Hixson

"At a time unlike any in the past, we must envision the future."

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Illinois Research

Contents

The Soybean

Soybeans — The Cinderella Crop

Since 1940, U.S. soybean production has increased dramatically. U.S. farmers produce nearly 60 percent of the world's soybeans. Illinois, the leading soybean-producing state, accounts for over one-sixth of U.S. soybean production.

Predicting the future is difficult, but for soybeans the future appears bright. Soybeans are unique in that the seed is rich in both high-quality protein and oil. Soy oil has a lower level of saturated fatty acids than most oils of plant origin. Demand for both soy oil and meal probably will increase as the economies of importing nations improve. Rapid increases in cereal grain production in developing countries will increase the demand for oils and animal products, and stimulate world demand for soybean meal as a protein supplement.

New uses will continue to be discovered for soybeans. For instance, biodegradable soybean oil has recently replaced petroleum-based carriers in the printing ink for some newspapers. This substitution reduces health hazards and pollution. Soybean oil can also be used to control dust in grain elevators and may partially replace diesel fuel in the future.

Plant breeders will continue to improve the agronomic traits of the soybean, and genetic engineers will radically modify the quality and quantity of the oil, protein, and other constituents to adapt them to specific needs. Soy oil with modified fatty acid composition may replace coconut, palm, and other imported tropical oils. Over one billion pounds of coconut oil, an oil rich in lauric acid, are used annually in the United States, largely in detergents. Soybean oil is low in lauric acid, but researchers are trying to increase it. Illinois researchers have markedly reduced the trypsin inhibitors, which interfere with the digestion of unprocessed soy protein by animals. If additional antinutritional factors are removed, soybeans will be fed to livestock without energy-intensive processing.

Although soybeans are mainly used for livestock feed in the United States, they have considerable potential as food for humans. Soybeans contain omega-3 fatty acids, which help reduce heart disease. Nutritional factors in the soybean can be improved, and taste factors that affect its suitability for food will be modified.

Also in the future, resistance to several herbicides will be incorporated into the soybean. For instance, when resistance to glyphosate is incorporated, farmers can use Roundup as a postemergent herbicide to eliminate all the plants in a soybean field except the soybean. As biological control of insects and other pests becomes more prevalent, dependence upon insecticides and fungicides will be reduced.

Rapid change will continue to characterize the soybean industry. Changes caused by economic, social, or political factors are more difficult to predict, but application of molecular genetics and tissue culture will drastically modify the soybean of the twenty-first century. Scientific advances will lead to greater utilization of soybean products and to more efficient soybean production.

Lawrence E. Schrader, professor and head, Department of Agronomy

Soybeans in Illinois

The story of the soybean is one of the most unusual in agriculture. Barely known — indeed, an object of curiosity — a hundred years ago, the soybean is now the second most important crop in American agriculture. A significant generator of the technological revolution of the twentieth century, the soybean has made the transition from draft animals to machine power possible and expanded the poultry and swine industries. The benefits, of course, were reciprocal. Mechanization made land available for the production of soybeans, and the poultry and swine industries and other industries provided markets.

Soybean markets are tight now: competition is intense. Other commodities compete for domestic markets; and along with other soybean-producing nations, Argentina, Brazil, and China — the ABCs of soybean competition — vie for the international arena of trade. No longer are there insatiable demands for soybeans and soybean products. But there are unfulfilled human needs for nutritious foods, needs that could be satisfied by the soybean because of its incomparable balance of nutritional elements. And there is a vast potential use of soybean oil and protein as feed stocks for chemical synthesis as diminishing supplies of fossil materials become more scarce and more costly.

Illinois's leading role. Illinois is the leading state in soybean production, processing, and marketing. For more than 50 years, Illinois has had more soybean acreage than any other state. In all but one of those years, Illinois soybean production topped that of all other states. In 1986, total production on 9.15 million acres in Illinois was 366 million bushels — about 3 million more bushels than its nearest competitor, Iowa. Estimated acreage for 1987 is 8.9 million acres. Illinois also has the largest processing capacity, and the pricing system for buying and selling soybean contracts on the Chicago Board of Trade is based on delivery to Decatur. Illinois rail and river terminals are principal sources of soybeans moving into international markets.

The dominance of Illinois in the soybean industry is no accident. Illinois farmers, industrialists, researchers, and educators have been leaders in the introduction of soybeans and the growth of the industry since its beginnings. Pioneer Illinois farmers, such as William H. Stoddard of Carlinville, were soybean advocates a hundred years ago. A.E. Staley, Eugene D. Funk, Sr., and other processors of great vision offered guaranteed markets and prices to induce farmers to grow soybeans. Educators at the University of Illinois, including William L. Burlison and Jay C. Hackelman, urged farmers to consider planting soybeans and encouraged research to improve soybean production in Illinois. The introduction of soybeans into the English colonies and into Illinois is discussed in this issue by Theodore Hymowitz.

Early publications. Research on soybeans began at the University of Illinois almost as soon as the Agricultural Experiment Station was established. The first Experiment Station bulletin on soybeans was Bulletin 43 (Hopkins 1896). It reported the

findings of a study conducted the year before on the feeding value of soybean ensilage for steers. A year later Circular 5 (Davenport 1897) appeared with information on soybean production practices. Work on food uses began in the Department of Home Economics in 1930. The following year saw a research report, "Soybean Oil as Human Food." That early work included the use of soybean oil in potato chips, doughnuts, desserts, mayonnaise, and ice cream. Green soybeans were incorporated into various recipes.

Success with breeding. The crop's success owes much to soybean breeders. They transformed early introductions from black-seeded, viney, shatter-prone, or disease-susceptible types into varieties that fit well in farming systems and fulfill market demands for oil and protein. Scientific breeding began at the University of Illinois when Clyde M. Woodworth joined the faculty in 1920. He produced the first map of soybean chromosomes and developed the first varieties from directed hybridization.

In 1936, Illinois was chosen as the location of the U.S. Regional Soybean Industrial Products Laboratory, a cooperative venture of the U.S. Department of Agriculture (USDA) and several midwestern agricultural experiment stations. Until recently, varieties available to farmers were developed almost entirely in the cooperative program of the states and the USDA. But during the last few years, as John Schillinger notes in his article, varieties developed in the private sector have offered Illinois farmers a much wider choice. A soybean breeding program was also established at Southern Illinois University-Carbondale. Varieties from this program first became available to farmers this year.

A germplasm collection of almost 10,000 entries housed at the University of Illinois and new genetic engineering techniques ensure further improvement. In the future, we may see specialized types of beans with higher levels of oil and protein; higher levels of unsaturation or more omega-3 acids for better health; short-chain acids for purposes now served by palm or coconut oils or for industrial uses; higher levels of methionine; and possibly varieties intended for cooking as a vegetable. Richard Bernard and Theodore Hymowitz treat soybean genetics and breeding in more detail.

Advances through research. Soybean diseases have been studied at least since the arrival of pathologist Benjamin Koehler in 1924. Koehler published what was described as the "first paper on soybean diseases" in the *Soybean Digest* in 1941. Nearly 40 years later, a classic compendium of soybean diseases was published by University of Illinois pathologist James B. Sinclair and the American Phytopathology Society. Diseases have been a constant threat. Development of varieties that are resistant to the soybean cyst nematode, Phytophthora rot, and other diseases has done much to ensure the growth of the industry.

Weeds have always infested soybean fields and are the most costly pest problem. It took a while to produce good chemical weed control for soybeans because 2,4-D and other early herbicides were selective for broadleaf plants; that is, they were as damaging to soybeans as to their weed targets. When suitable chemicals became available in the 1960s, chemical weed control in soybeans quickly became the standard practice. Integrated Pest Management, the tool of the 1980s, economically and environmentally provides the most effective control. Loyd Wax, Barry Jacobsen, and Marcos Kogan discuss pest problems and controls for soybeans in their article.

Soybean physiology research at the University of Illinois is exceptionally strong, particularly in the areas of photosynthesis and nitrogen metabolism. Established in 1965 by the USDA, the soybean photosynthesis unit has won worldwide recognition and grown into a campus-wide group studying photosynthesis at all levels, from the molecular to whole plants in the field.

Although the utilization work of the USDA was transferred in 1942 to the Northern Regional Research Center at Peoria, research in soybean utilization has grown in the University of Illinois Department of Animal Sciences, the Department of Food Science, and Division of Foods and Nutrition. In this issue, Alvin I. Nelson and Lun Shin Wei discuss their work on soy beverages and other soy foods, and Barbara Klein treats the broader aspects of soybeans as food. Although foods comprise only a small part of U.S. soybean usage, they are increasing in favor and availability. Oriental diets use soybeans directly, and food uses dominate the soybean economies of China and Indonesia.

Comparing the performance of a wild soybean and a domesticated variety on the Agronomy/Plant Pathology Farm of the University of Illinois is Richard Bernard, curator of the Northern U.S. Soybean Germplasm Collection.

The Soybean Comes to Illinois

The soybean was domesticated by farmers in the eastern half of North China. Domestication is a process of trial and error and not an event. In the case of the soybean, this process probably took place during the Shang dynasty (ca. 1700-1100 B.C.) or perhaps earlier.

By the first century A.D., with the birth and degeneration of Chinese dynasties and the consequent consolidation of territories, soybeans spread from the eastern half of North China to northeast, central, and south China and to peninsular Korea. From the first century A.D. to the Age of Discovery in the fifteenth and sixteenth centuries, soybeans were introduced and established in Japan and in southeast and southcentral Asia. This expansion came with the development of the "silk road" and other sea and land trading routes, and accompanied the emigration of the Thais and other tribes from China. It continued with the rapid acceptance of the soybean as a staple food by Indonesians and other peoples.

The soybean reached North America quite late. It was first introduced in 1765 by Samuel Bowen, a seaman employed by the East India Company. Bowen brought soybeans from China via London to Greenwich, his residence in Savannah, the Colony of Georgia. Situated a few miles east of Savannah, the 450 acres of Greenwich became the center of his farming and manufacturing enterprises. On July 1, 1767, Bowen received patent number 878 for his invention of methods to prepare and make sago powder, vermicelli, and soy sauce from plants grown in America. The soy sauce that he manufactured in Georgia was exported to London.

In 1851, the soybean was introduced into Illinois by Benjamin Franklin Edwards, the youngest brother of the first territorial governor of Illinois, Ninian Edwards (from whom Edwardsville, Illinois, takes its name). He obtained the seeds from Japanese fishermen who were rescued at sea by the "Auckland," which was bringing sugar from Hong Kong to San Francisco. Edwards gave the seeds to John H. Lea of Alton, who planted them in his garden in the summer of 1851. By 1854, the soybeans brought to Illinois in 1851, were multiplied, disseminated, and evaluated by farmers throughout the United States.

Theodore Hymowitz, professor of plant genetics ☐

International importance. Economic studies on the costs and prices of soybeans were reported by Harold Clayton M. Case as early as 1924. For more than three decades, soybeans have been a significant component of international trade. Foreign currency generated by the sale of soybeans and soybean products as well as other agricultural products is an important factor in reducing trade deficits.

Changing grades and standards. As international competition for soybean markets has intensified, so have problems with the quality of soybeans reaching foreign customers. Recently, attention has turned to in-transit causes of deterioration and to an improved definition of quality standards. Recent and possible future changes in grade and quality standards are explained by Sinclair and Lowell D. Hill. Standards should provide a reliable description of important quality factors to buyers and a fair price based on quality to producers. University of Illinois scientists have worked closely with industry groups and governmental regulatory authorities on the problem.

A teaching tool. Soybeans have played a special role in the international educational activities of the University of Illinois College of Agriculture. This crop was the tool used in India to demonstrate the land-grant concept of the partnership among teaching, research, and extension. Later the International Soybean Program (INTSOY) conducted programs in Sri Lanka and Peru. Beginning in 1973, INTSOY developed cooperation with more than 100 countries. Cooperation in variety evaluation and production studies was important, but utilization, especially at the village level, was a major activity. INTSOY efforts now are concerned almost entirely with utilization. The work on utilization by Nelson and Wei in the Department of Food Science has been financed mostly with money from the U.S. Agency for International Development and other internationally earmarked funds.

Cooperation in the industry. Soybean farmers, processors, and marketers have cooperated very effectively to obtain support for research and market promotion. They have been instrumental in obtaining increased personnel and financing from state and federal governments, and they have invested substantial sums of money from farmers and the industry in research grants and market development. Nearly all soybean states have adopted "check-off" plans that call for withholding at the first point of sale contributions of from 1/2 cent per bushel in Illinois to 2 cents per bushel in Wisconsin. These funds are used for market promotion and for research and education. In Illinois the check-off program is administered by the Illinois Soybean Program Operating Board (ISPOB), which was established in 1974 and is based in Bloomington. The ISPOB has invested $4.4 million in research grants to the University of Illinois at Urbana-Champaign, Southern Illinois University-Carbondale, other universities in the state, and to the American Soybean Association Research Foundation. The National Soybean Processors Association was a major contributor to overseas marketing programs before the adoption of check-offs, and its funding was a major force in expanding and strengthening soybean physiology research.

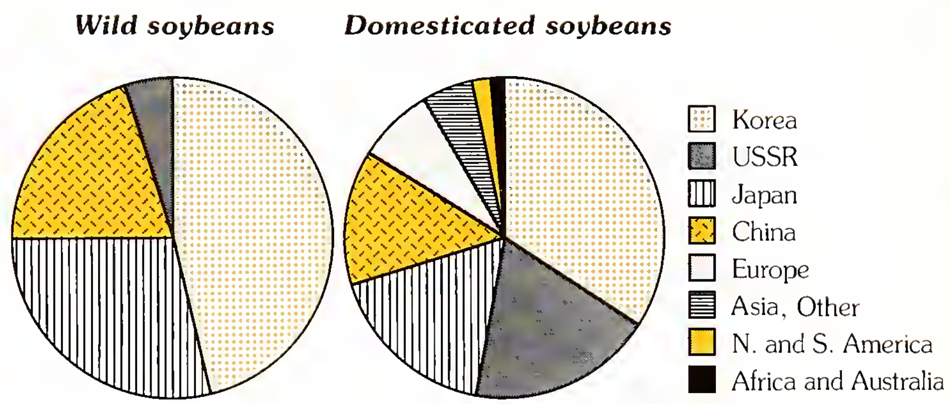
Robert W. Howell, professor emeritus, agronomy ☐

The U.S. Soybean Germplasm Collection: A National Resource

On the Agronomy/Plant Pathology Farm of the University of Illinois at Urbana-Champaign is a resource that plays a major role in the success of soybean production and utilization in this country: the Northern Soybean Germplasm Collection of the U.S. Department of Agriculture (USDA). Maintained as part of a joint project between the University of Illinois and the USDA, this collection contains the seeds of over 8,000 varieties and strains of soybeans, wild soybeans, and other closely related species. The curator of the northern collection is Richard L. Bernard. Another collection containing 3,000 soybean varieties and strains from the lower latitudes is maintained by the USDA at the agricultural experiment station in Stoneville, Mississippi. The curator of the Southern Soybean Germplasm Collection is Edward E. Hartwig.

Bernard and Hartwig are responsible for preserving all the varieties and strains in the collections by keeping the seeds at 7-percent moisture and 50°F (10°C) in cold storage and growing them to replenish the seedstocks as needed. Investigators are provided packets of seeds upon request. Last year from the Urbana collection 13,000 seed packets were sent to 314 people in 31 states and 26 foreign countries.

Growing exotic varieties. Every year over 1,000 of these exotic varieties are grown at the University of Illinois. These varieties often require special handling. Some ripen as early as the last week of July; some are very viney and grow flat to the ground, shatter profusely, or occasionally pro-



Percent of Soybeans in the USDA Soybean Germplasm Collection Contributed by a Country or Continent.

Table 1. Number of Strains in the USDA Soybean Germplasm Collection by Countries or Continents of Origin

	Collection		
Domesticated soybeans	**North**	**South**	**Total**
Korea	2,035	1,321	3,356
USSR	1,798	42	1,840
Japan	1,044	642	1,686
China	1,214	113	1,327
Europe	758	0	758
Asia, Other	18	467	485
North America	69	52	121
Africa	1	114	115
South America	7	58	65
Australia	6	24	30
Total	6,950	2,833	9,783
Wild soybeans			
Korea	42	272	314
Japan	8	185	193
China	116	20	136
USSR	34	0	34
Total	200	477	677

duce no seeds at all because of disease or late maturity. The wild soybean is even more difficult to grow and harvest: its small viney plants are susceptible to virus and leafhoppers, and its tiny seeds are produced in pods that shatter the day the pod ripens. The other related species native to Australia and the South Pacific must be maintained in the greenhouse and require intensive care.

Another responsibility of these curators is to attempt to gather all of the soybean genetic resources of the world, especially focusing their efforts on eastern Asia, where the wild soybean is native and the soybean has been grown for centuries. The results of these efforts to date are given in Table 1 and the accompanying figure, which show the current makeup of the collection by country of origin.

Table 2. Germplasm Sources of Resistance to Specific Pests, A Partial List

Pest	Geographic origin of resistance	Date introduced	Presence in Illinois varieties
Bacterial pustule leaf spot	Nanjing, China	1927	Williams and many others, including all southern U.S. varieties
Brown stem rot	Fusan, Korea	1930	Chamberlain, BSR 101, BSR 201, BSR 301, BSR 302
Phytophthora rot (25 known races)			
19 races	Beijing, China	1906	Williams 82
15 races	Pyongyang, Korea	1914	Williams 79
11 races	Shenyang, China	1920	Union
Downy mildew			
Several races	Pyongyang, Korea	1930	Union
Several races	Dalian, China	1930	Fayette, Cartter
Soybean cyst nematode			
Races 1 and 3	Beijing, China	1906	Franklin, CN210, CN290
Races 3 and 4	Dalian, China	1930	Fayette, Cartter
All races	Leningrad, USSR	1980	Being developed
Phomopsis seed decay	Hiratsuka, Japan	1977	Being developed
Soybean mosaic virus			
Several races	Sariwon, Korea	1932	Being developed
Several races	Tokyo, Japan	1971	Being developed
All races	Tokyo, Japan	1971	Being developed
Soybean rust			
Several races	Shikoku, Japan	1952	Being developed
Several races	Tokyo, Japan	1956	Being developed
Several races	Pant Nagar, India	1981	Being developed
Mexican bean beetle, soybean looper, and other leaf feeders	Kanagawa, Japan, and Tokyo, Japan	1948 1955	Being developed

Contributions from Asia. The soybean industry owes a debt of gratitude to those countries that have contributed their soybean germplasm to the U.S. collections either by sending us their collections or by permitting or assisting collectors from the United States. The generosity of South Korea is notably obvious in the statistics. Last year Japan sent over 1,000 varieties, which when catalogued will be added to the figures of Table 1. The USSR has been a major contributor. This fact is especially important because the Soviet Far East extends into areas where the wild soybean is native. These areas, moreover, have produced soybeans for centuries. Even China, potentially the biggest contributor, has recently donated commercial varieties despite its political ban on the exchange of soybean germplasm.

Bernard and Hartwig also provide a general agronomic evaluation of each germplasm entry as well as data on the composition of the seeds. These data are made available through periodical publications and the USDA Germplasm Resources Information Network, Beltsville, Maryland. This new nationwide computer system is available to any researcher with a computer and the appropriate hookup.

Chinese ancestry. The history of soybean germplasm in this country contains many success stories. The first successful use of soybean germplasm, of course, was the commercial use of foreign varieties in the United States when soybeans were a new crop here. Among the several thousands of imported and tested Asian varieties, relatively few were selected and grown, and these varieties were mostly from northeast China. Until the mid-1940s, most midwestern soybean varieties were simply transplanted from China. The cultivar, 'Illini', for instance, was brought from northeast China in 1912. These Chinese varieties were intercrossed and selected for improved yield and plant type; therefore, the ancestry of most commercial soybean varieties grown in the United States traces back to soybeans introduced from China during the period from 1911 to 1927.

Table 3. Germplasm Sources of Seed Traits, A Partial List

Trait	Geographic origin of trait	Date introduced
High protein	Paris, France Sapporo, Japan Koryoho, Korea	1900 1929 1929
Amylase null	Norrkoping, Sweden	1951
Kunitz trypsin-inhibitor null	Suweon, South Korea	1947
Lectin null	Niuzhwang, China	1907
Lipoxygenase 1 null	Gyeongsang Nam Do, South Korea	1976
Lipoxygenase 2 null	Ohihiro, Japan	1930
Urease null	Baoding, China	1908

Gil Woon Chung, a Korean scientist who graduated from the University of Illinois, gathers wild soybeans in northwestern South Korea for the USDA soybean germplasm collections.

Improving adapted varieties. More recently, the germplasm collection has been used as a source of specific desirable traits, such as pest resistance and improved seed composition. In some cases, varieties with desired traits have been crossed with adapted varieties, and improved adapted varieties have been developed containing the desirable trait and the high yield of the adapted variety. Examples of some of these traits and their origin are given in Tables 2 and 3.

Resistance. Table 2 presents only a sample of the many sources of resistance to pathogens and pests afforded by the germplasm collection. Discovered long ago, the resistance of some of these sources is already present in commercial varieties. Other sources of resistance are still in the developmental stages. Two that offer much promise include an introduction from the Soviet Union that was recently found to be resistant to apparently all races of cyst nematode and a Japanese variety that was recently found to be resistant to Phomopsis seed decay. Phomopsis is the fungus that is involved in post-ripening seed rot. Considerable seed decay due to Phomopsis occurred last fall in Illinois when rain delayed the harvest. Because of this Japanese variety, soybean breeders may for the first time be able to breed varieties that are resistant to Phomopsis.

Work with proteins and enzymes. Other opportunities for improving the soybean are listed in Table 3. Several strains in this table occur with protein content as high as 50 to 55 percent instead of the usual 40 to 45 percent. Increasing this most valuable constituent of the seeds may be desirable. Other varieties have been found that lack certain enzymes or protein constituents. For example, the Kunitz trypsin inhibitor is a protein that reduces feeding value when raw soybean meal is fed to poultry and swine. Eliminating it from soybeans may lower the cost of processing or even allow raw soybeans to be fed. Lipoxygenase is believed to contribute to the rancidity that develops in stored soybean oil. Eliminating this enzyme from soybeans may lead to expanded uses of soybean oil. The function of other enzymes or proteins including B-amylase, lectin, and urease is less well understood, but the varieties that lack these enzymes or proteins are useful to researchers who are evaluating both their function in the soybean plant and their value in soybean products.

Crossing wild perennial relatives. In the future, additional germplasm may become available to the soybean breeder. Theodore Hymowitz and his co-workers at the University of Illinois have begun to investigate the potential use of wild perennial relatives of the soybean. With traditional methods, these wild perennial relatives cannot be crossed with the soybean or even wild soybeans. But by using newly developed tissue culture techniques, crosses with most of the twelve wild species are now possible, and techniques for obtaining seeds for backcrossing and gene transfer to the soybean are being worked out. There is also a very good possibility that researchers will find sources of useful traits not in soybeans, such as resistance to brown spot and other diseases to which all soybeans are susceptible.

Richard L. Bernard, USDA research geneticist with the Agricultural Research Service and professor of plant genetics, and Theodore Hymowitz, professor of plant genetics, both in the Department of Agronomy ☐

Soybean Variety Development in the Private Sector

Research in soybean variety development within the commercial seed industry began more than 20 years ago. It increased rapidly after enactment of the Plant Variety Protection Act of 1970, which provides variety developers with a patent-type control over the use of their varieties. Initially, this development enterprise involved only a few companies; but the number has grown until in 1987 it includes 31 companies, for which the annual research investment is estimated at more than $17 million. The number of breeder-researchers has grown to 67, with 12 located in Illinois.

This research investment has benefited the Illinois soybean producer in greater yield potential, better standability, and improved stability of performance among proprietary soybean varieties. Impressive releases in the late 1970s — varieties such as A3127 (Asgrow), S1492 (Northrup King), and CM203 (Midwest Oilseed, Inc.) — set the trend for higher yield levels; and recent proprietary varieties exceed even those standards. In addition, these newer releases offer growers greater protection against important diseases such as Phytophthora root rot. Increased demand for resistance-tolerance to soybean cyst nematode and to brown stem rot has resulted in new variety releases that offer greater protection against these increasingly serious yield reducers.

In the first years, the private research programs utilized varieties and germplasm released by public researchers. Now, however, much of the germplasm used in these programs originates in variety releases from the private sector. For example, in the 1986 Asgrow variety releases, more than 60 percent of parental germplasm came from privately developed varieties.

The private research programs have broadened the scope of soybean variety improvement by adopting strategies that allow a greater number of genetic recombinations to be handled effectively. In the Asgrow system alone, more than 20,000 new genetic families have been produced since 1974, with each family capable of having thousands of unique genetic recombinations within it. The private soybean breeders are annually evaluating well over a million new lines for the unique combination of genetic factors that enhances variety performance. Handling so many lines is possible because researchers have developed and adopted innovations in field plot design, screening techniques in the laboratory and greenhouse, and computer software and data-analysis systems.

Private breeders have also adopted new equipment systems that permit on-farm research testing of numerous new lines at multiple locations to determine more accurately the yield potential and performance stability. With these more efficient systems, Asgrow is able to conduct tests at 12 different sites in Illinois.

Commercial soybean breeders have reduced significantly the time necessary to repond to a production need or to release improved varieties. In the Asgrow system, an average of 7 years is required from crossing until seed is available to customers. Only 6 years were required for several varieties, such as A3307, a variety with cyst-nematode resistance. (By comparison, the Williams variety required 12 years.) The reduced time to release a new variety is primarily the result of successful winter nursery programs, which are vital for rapid generation advance and increase of breeder and basic seed classes.

As a result of the research advancements in the private sector, supported by germplasm releases from public scientists, the Illinois soybean farmer has access to soybean varieties that will incease the return on seed and crop production investments. With the State of Illinois testing more than 500 entries annually, the challenge for the Illinois farmer is in choosing the best varieties for specific, individual needs.

John A. Schillinger, executive director, research, Asgrow Seed Co. □

In Search of Soybean Quality

Research on soybean seed quality at the University of Illinois is conducted by a team of agricultural engineers, food scientists, plant pathologists, and agricultural economists. Legislators seeking a solution to problems with grain quality found some answers in the testimonies of several of these scientists at the U.S. Congressional hearings held in Urbana in July 1986. Their research, therefore, is especially important at a time when increased export competition calls for the art of listening to those who buy our soybeans and soybean products.

Much of the debate about grain quality is centered on soybean grading standards developed in the early 1920s by the newly formed American Soybean Association. These voluntary grades were adopted almost intact as official U.S. grades under a 1940 amendment to the 1916 Grain Standards Act. The lowest grade was labeled as "sample," when 10 percent or more of a sample of 100 seeds showed damage (Figure 1). Grades facilitate buying and selling without each customer's having to personally examine each lot to determine its value. But which factors and factor limits to include as measures of value are an issue that has generated heated debate for many years.

Revising the standards. Although the official standards settled on some characteristics that have traditionally been considered indicators of quality — test weight, splits, damage, foreign material, color, and moisture content, researchers have long suggested using characteristics that provide information about the yield and quality of meal and oil. In addition to oil and protein quantity, estimates of value require information about the content of free fatty acids, hydratable phosphatides, and other chemical properties.

If information on end-use value were incorporated in the price of soybeans, it would provide economic incentives for changes in cultivars and cultural practices to deliver the product Japanese and European customers are eager to buy. A survey of European processors in 1986 revealed that 68 percent always test soybeans for damage levels at their plant; 84 percent test for oil content; 79 percent for protein content; and 58 percent for free fatty acid. U.S. grades provide information on only one of these factors — damage, and even that factor is based on a subjective determination that differs significantly from the definition of damage used by foreign processors. Research by Lowell D. Hill and his associates in the Department of Agricultural Economics at the University of Illinois indicated that the grades established in 1924 no longer meet the needs of current sophisticated producers and processors.

Studying the history and development of U.S. grain standards helps one understand the issues involved in the debate. Solutions to the problems with grain quality often are found in the actions of the past and economic incentives of the future. The viewpoints of others in the debate must be analyzed. In conjunction with the Farm Research Institute, farmers in Illinois, Indiana, and Iowa were surveyed to identify practices that influence quality and their preferences for alternative solutions. Currently, producers receive payments based on the lowest quality of beans in a load. Many producers indicated a willingness to accept discounts for low-quality beans if beans of above average quality were rewarded.

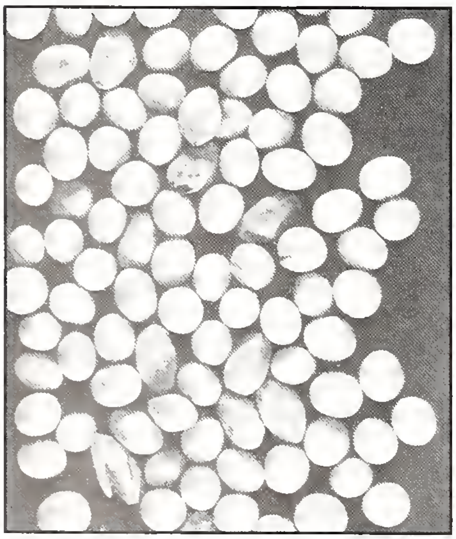


Figure 1. Sample grade, the lowest of the USDA's five grades, received the lowest prices at the elevators.

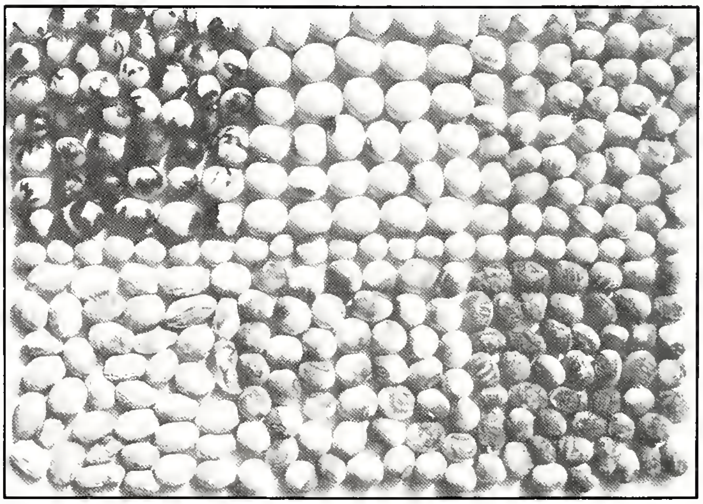
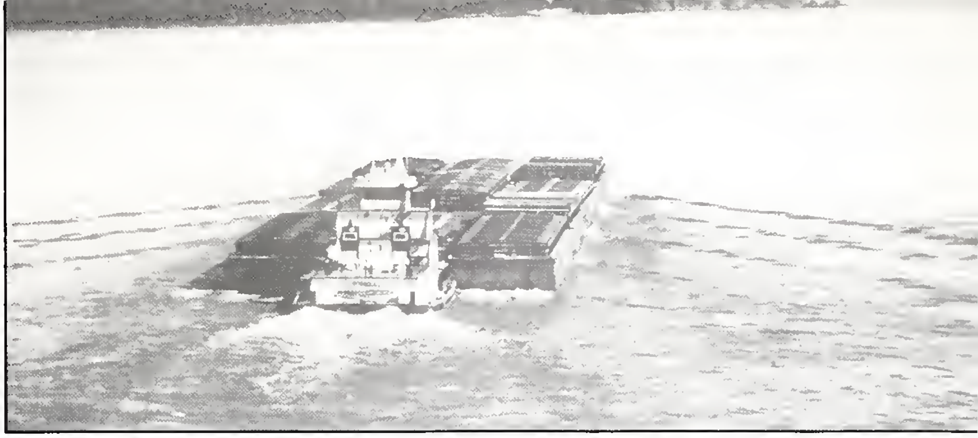


Figure 2. Symptoms produced by seed-borne pathogens (clockwise from upper right): soybean seeds with a light brown hilum ring from infection by the soybean mosaic virus; seeds infected with *Cercospora sojina* (frogeye leafspot fungus); seeds infected with the *Cercospora kikuchii* (purple seed stain fungus); seeds infected with the *Diaporthe/Phomopsis* complex (Phomopsis seed decay); seeds with a dark hilum ring from infection by the soybean mosaic virus; and seeds without symptoms.



Response to research. The discussion and input of researchers, however, are starting to bear fruit. In addition to some changes made in the U.S. standards for soybeans in 1985, which included the removal of moisture as a grade-determining factor, quality requirements were tightened on September 1, 1986, by the Federal Grain Inspection Service (FGIS) through changes in five of the ten interpretive line slides. FGIS inspectors use these slides to visually determine the severity of damage present in soybean kernels before they are graded.

Yet "damage" itself is a very subjective criterion for grading soybeans. What are damaged seeds? According to recent grading standards for soybeans, stained, mottled, or discolored seeds are considered "damaged." The discoloration of soybean seeds is attributed to various vague causes: mold, frost and immature green damage, natural weathering, and ground damage.

Mold. Discolored and moldy soybean seeds have been a serious problem in both domestic and international markets.

Green seeds. Green seeds come from harvesting grain before it is ripe or from plants killed prematurely by freezing or other causes. Production of green seeds is common in the northernmost growing areas of the United States. Fields that have been flooded or have suffered from drought also are common sources of green seeds. Price discounts for these seeds are justified because they cause serious problems in industrial uses.

Weathering. "Weathering" is a term that is obsolete because discoloration, except in the case of green seeds, is due to specific biological factors. Research by James B. Sinclair and his co-workers in the Department of Plant Pathology has shown that the types of discoloration and "moldy" seeds come from colonization by fungi and bacteria and from the soybean mosaic virus while the beans are still in the field (Figure 2).

Field fungi. The so-called "field fungi" associated with soybean seeds vary in the amount of discoloration they cause. For example, the fungus that causes downy mildew disease, *Peronospora manchurica*, leaves a white, crusty growth on the surface of soybean seeds (Figure 3). The growth is superficial, causes no damage to the seed, and can be easily removed mechanically. Seeds with signs of this disease should not be docked. Those fungi that cause the greatest amount of discoloration, which may or may not affect the standards for grain quality, are species of *Alternaria*, *Cercospora*, *Colletotrichum*, *Fusarium*, and the *Diaporthe/Phomopsis* complex. Discounts are justified for some discoloration caused by fungal infections. Other discolorations should not affect the price because they do not affect the value of the grain in processing. Sinclair and his co-workers aim to define these differences and how to measure them qualitatively. Besides the soybean mosaic virus, only two or three of the ten microorganisms known to discolor seeds have been studied to determine how they affect grain quality and value-added products. Sinclair is currently attempting to differentiate more accurately between "real damage" and "cosmetic damage" caused by seedborne fungi, bacteria, and the soybean mosaic virus. The effect of these pathogens on viability, free fatty acid content, oil and protein content, and on value-added products, such as flour, oil, and extruded products is being studied.

Storage fungi. There are other types of fungi that cause damage to soybean seeds during shipping and storage. Always present, these "storage fungi" are usually species of *Aspergillus* and *Penicillium* (Figure 4). Their growth in storage deteriorates, heats, scorches, or burns soybean

Figure 3. A soybean seed encrusted with the superficial dry mold of *Peronospora manchurica*.

Figure 4. Soybean seeds from storage showing the growth of *Aspergillus* sp., *Phomopsis* sp., and other molds.

seeds. They are easily controlled when soybean seeds are stored under proper humidity and temperature.

Of real importance to soybean quality is what the particular damage does to the end-use value of the soybean, that is, its yield of valued products, rather than how it affects the visual appearance of the bean. When the 1986 soybean crop turned out to be heavily infected with field molds, many farmers and elevators in Illinois and elsewhere encountered unforeseen problems. Research findings convinced FGIS that one of the new interpretive line slides was unnecessarily restrictive in its depiction of surface mold, which does not affect the processing value of the soybean kernel. After studying the results of the research, FGIS relaxed this interpretation on September 24, 1986.

Although this action helped many farmers against unjustified discounts, it may also have reinforced the widespread perception that grain quality is a political issue. Frequent market-disrupting changes are likely to reoccur until a clear relationship is established between the characteristics of raw beans and the value of processed products. The Department of Agricultural Engineering is working on new methods and equipment for objective measures of these factors.

Discussions about soybean quality are continuing, encouraged by research and political interest. FGIS itself is studying how to refine the methodology for rapidly measuring oil and protein content. It will consider proposing that these factors be included in future standards. A study also is underway to improve the current method for assessing soybeans damaged by stink bugs (Figure 5). Possible changes will be addressed when these studies are completed. The comments on excess foreign material and the current provisions for foreign material will be given consideration during the next review of soybean standards. Research on soybean quality by the team of specialists at the University of Illinois at Urbana-Champaign will help assure the usefulness and equity of such changes.

James B. Sinclair, professor of plant pathology, and Lowell D. Hill, professor of agricultural economics ☐

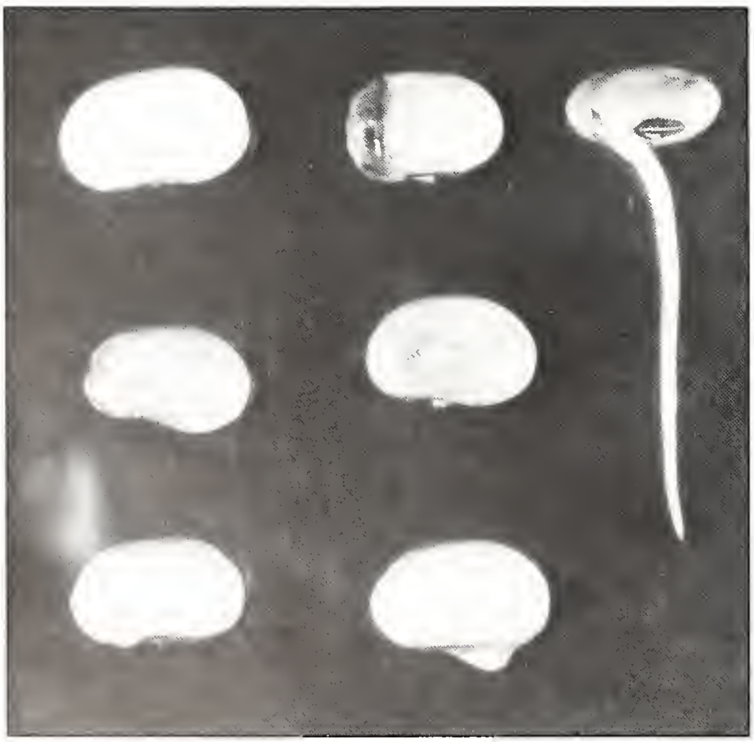


Figure 5. Soybean seeds with symptoms of stink bug damage. The injuries made by the stink bugs provide entry for a variety of fungi that decay the seeds.

Managing Soybean Pests

Each year pests cause losses of 10 to 30 percent of the Illinois soybean crop. Management of weeds, plant diseases, and insects, therefore, is an important aspect of soybean production. These pests, moreover, may interact on the crop and require an informed, integrated approach to pest management that provides control with minimum cost and maximum safety to the crop, producers, and the environment.

Weeds. Losses due to weeds may be as high as 20 percent, when the current costs of control are added to losses in yield and quality. In Illinois, for instance, losses average about 10 percent of the yield annually, and control measures cost an additional 10 percent of the value of the crop.

Annual broadleaf weeds usually cause higher losses per weed than do annual grasses. Velvetleaf, cocklebur, annual morningglories, and jimsonweed are prevalent, competitive, and sometimes hard to control. In localized areas, pigweeds, lambsquarters, smartweeds, and ragweeds, as well as black nightshade, can reduce yields and cause harvesting problems. Giant foxtail is often the most prevalent grass, but barnyardgrass, yellow and green foxtail, panicum, and crabgrass may be important. Volunteer corn, which often acts as a weed in soybean fields, is very competitive. Shattercane may infest river-bottom areas, whereas wild proso millet occurs in northern Illinois. Perennial grass weeds, including johnsongrass in southern areas and quackgrass in northern areas, infest Illinois soybean fields. Milkweeds, hemp dogbane, thistles, bindweeds, bigroot morningglory, and other especially hard-to-

control perennial broadleaf weeds are found in several areas of the state.

Control involves both chemical and nonchemical measures. Nonchemical measures consist primarily of preplanting tillage, postplanting cultivation, using weed-free seed, and following good crop rotation practices. Virtually all soybean acreage in Illinois receives at least one application of a herbicide. These treatments are usually applied either to the soil before planting and mixed into the soil with a tillage tool when incorporated "preplanting," or they are applied to the soil surface "preemergence" — shortly after planting and before either the crop or weeds emerge. A recent trend is the use of herbicides that are both effective and safe to apply "postemergence" — after the crop and weeds have emerged. Many fields are treated with combinations of herbicides to provide broad-spectrum control and to reduce the danger of injuring the crop. Sometimes, sequential applications are needed. A preplanting treatment, for instance, may be followed by a postemergence application.

Optimum use of chemical control measures requires the mapping of fields for the types of soil and weeds that are present. Chemical and nonchemical means are available to manage most of the weed problems in soybean fields.

Research at the University of Illinois on current management problems is also designed to solve problems that seem to be evolving with changing tillage practices. One of our overall objectives is to reduce the costs of soybean production while maintaining an acceptable level of weed management.

Edward Stoller, a plant physiologist

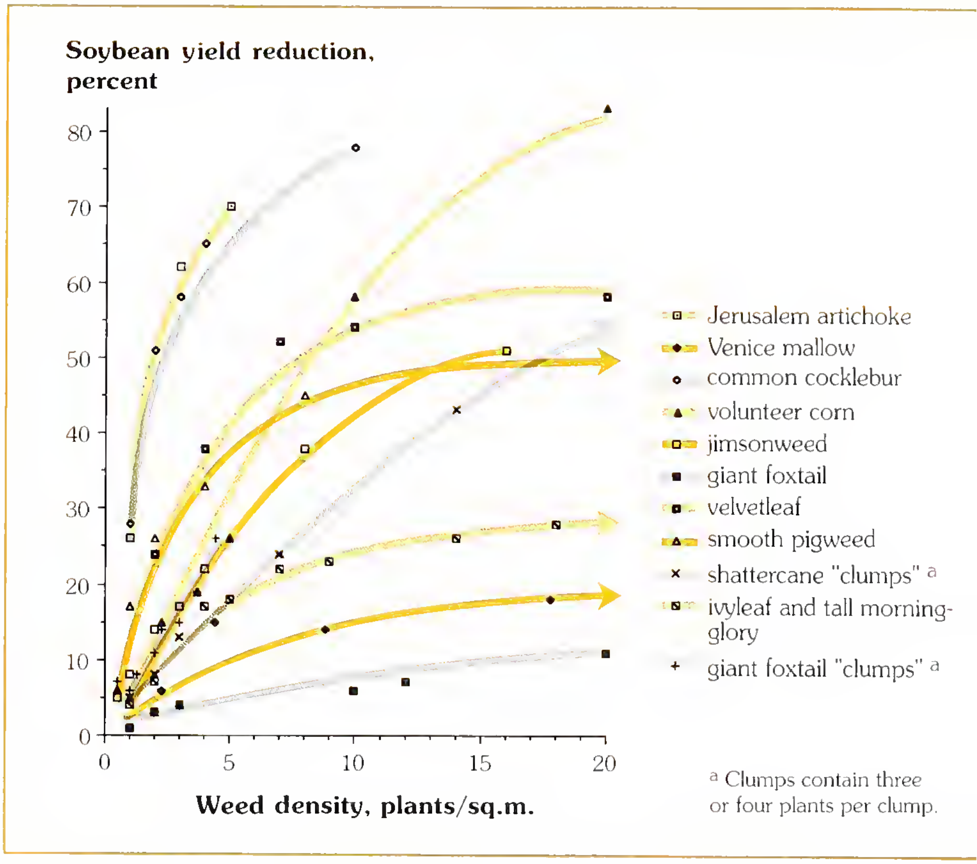


Figure 1. The effect of increasing weed density on soybean yield reduction for ten weeds when allowed to interfere with soybeans for the entire season. (Note: Data for figures 1,2, and 3 are from E. W. Stoller et al., *Reviews of Weed Science*, Volume 3, 1987. In press.)

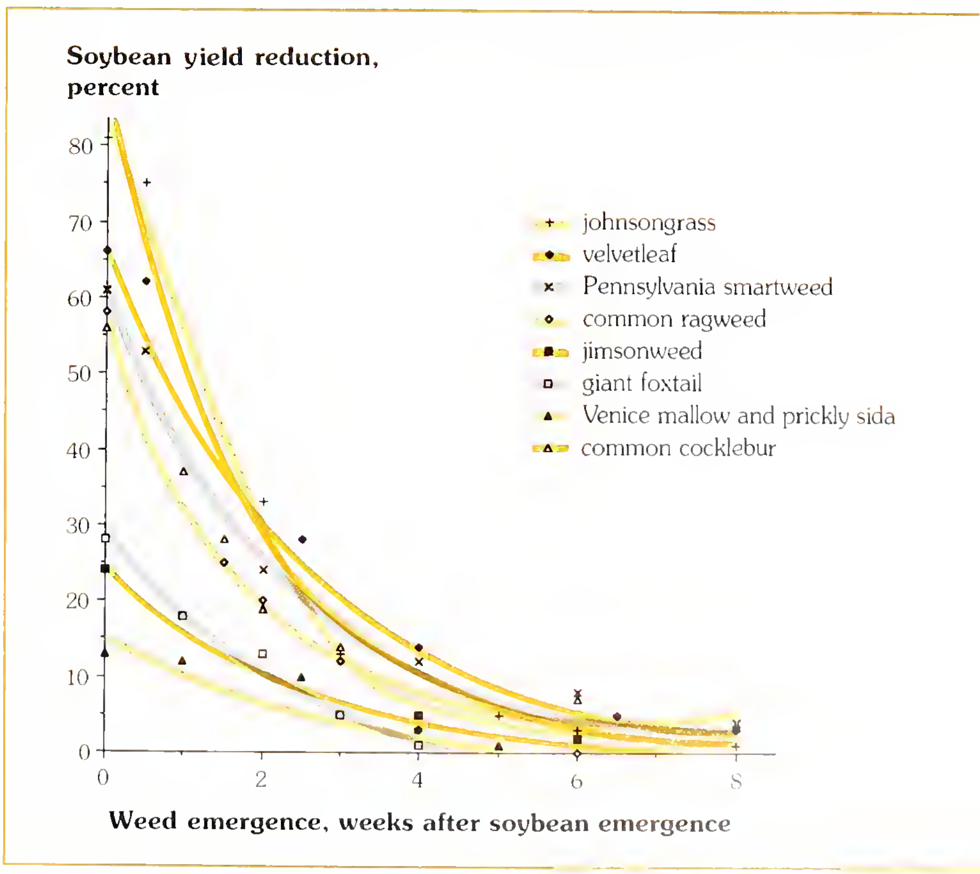


Figure 2. The effect of time of weed emergence on soybean yield.

with the USDA who heads the work on weed ecology and weed biology at the University of Illinois, is examining weed species to find exploitable vulnerabilities. Our interference studies reveal the competitive differences of weed species at various densities (Figure 1), show the length of preemergence control needed after planting (Figure 2), and allow us to determine how long we can wait to initiate postemergence control measures (Figure 3).

Rex Liebl in the Department of Agronomy at the University of Illinois is currently investigating the physiological basis of selectivity and the mode of action of herbicides in his search for greater crop tolerance to existing herbicides. With Ellery Knake, Loyd Wax, and others, he is also evaluating new herbicides and combinations of herbicides to help determine their effectiveness under a wide variety of conditions and to point out potential problems.

In herbicide-soil interaction studies, researchers at the University of Illinois are investigating the movement and degradation of herbicides. Several new herbicides have potential problems with excessive persistence: in some conditions, they may injure the following rotational crop.

Studies on herbicide application done in cooperation with agricultural engineers at the University of Illinois focus on methods of incorporating soil applications and on tests to increase the effectiveness of foliar applications by reducing spray volumes, using certain spray additives, and minimizing the off-target drift of herbicides.

Other cooperative research with agricultural engineers is on developing optimum methods of weed control

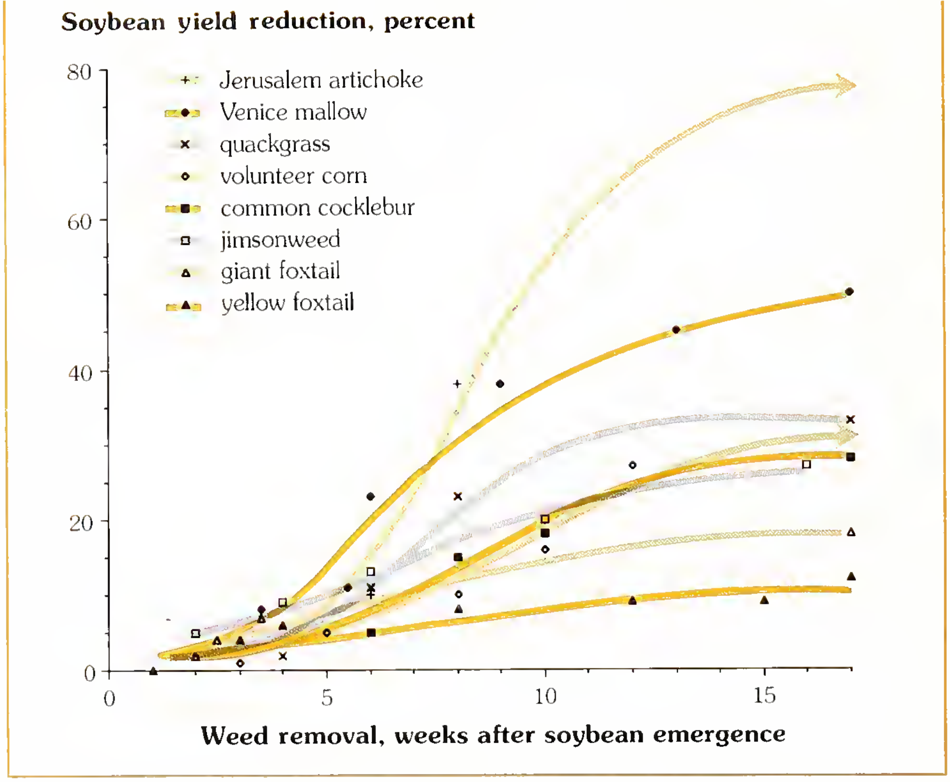


Figure 3. The effect of time of weed removal on soybean yield. (See note, Figure 1.)

when using different tillage systems and methods of crop rotation. Still other cooperative research involving the plant protection disciplines, economists, and agricultural engineers, is being conducted to develop the optimum pest management regime over a variety of locations, tillage systems, and crop rotations. In addition to optimum pest control, a major objective of these studies is to identify the systems that provide the best economic return to the grower.

Diseases. Soybean diseases may reduce yields in Illinois by 10 to 15 percent each year. About 25 different diseases are responsible for these losses. Although several soybean diseases can be present in any field, total yield losses from all diseases rarely exceed 20 percent. The relative risk of losses from various soybean diseases can be seen in Figure 4. These yield losses can be reduced by a comprehensive disease management program that includes all four of the basic methods of control: exclusion, eradication, protection, and planting disease-resistant varieties. Barry J. Jacobsen has developed such a program for Illinois.

Exclusion. Exclusion is an important control strategy that is the primary focus of plant quarantine laws. Many current disease problems as well as weed and insect pests in Illinois are not native and could have been excluded by current quarantine programs.

Eradication. Eradication is the elimination or reduction of a pest population after it has been established in a production field. Many soybean pathogens can be controlled by reducing or eliminating them between soybean crops through crop rotation because these pathogens die out when the residue of their soybean host crop decays or when there are no host soybeans or other host plants on which to reproduce. Economically important soybean diseases controlled at least in part by rotation include soybean cyst nematode (SCN), brown stem rot, Septoria brown spot, Anthracnose, pod-and-stem blight, bacterial blight, and bacterial pustule.

Diseases not controlled by rotation are those that can infect a wide range of hosts, those that form long-term survival structures, and those that are spread by insects or windblown spores. Soybean diseases in this group include

Phytophthora root rot, charcoal root rot, Pythium root rot, lesion nematode, powdery mildew, and virus diseases.

Protection. Crop protection is another major tool used in disease management programs. Soybeans can be protected by fungicides, nematicides, proper fertility programs, planting high-vigor seed, and selecting environmental conditions that do not favor the development of diseases. The use of fungicides and nematicides in protection schemes has been fine-tuned by research programs that identify economic injury levels (EIL) so that these pesticides will be used only where needed and with positive economic results. These programs have produced guidelines for fungicide seed treatments that are based on seed lot germination and on the percentage of seeds infected with pod-and-stem blight; scouting techniques and guidelines for using foliar fungicides; and economic thresholds for soybean cyst, dagger, and root lesion nematodes. The annual economic returns from this research are certainly in the millions of dollars. Of particular interest is the model for economic threshold developed for SCN by Greg Noel, a USDA research nematologist in the Department of Plant Pathology. This model predicts yield loss from the number of nematodes in soil samples submitted by growers. On the basis of this model, the Cooperative Extension Service makes recommendations for nematode management, such as rotation, planting a resistant variety, or nematicide treatment.

In the future, commercial biological control agents may be added to the existing arsenal of protection tools.

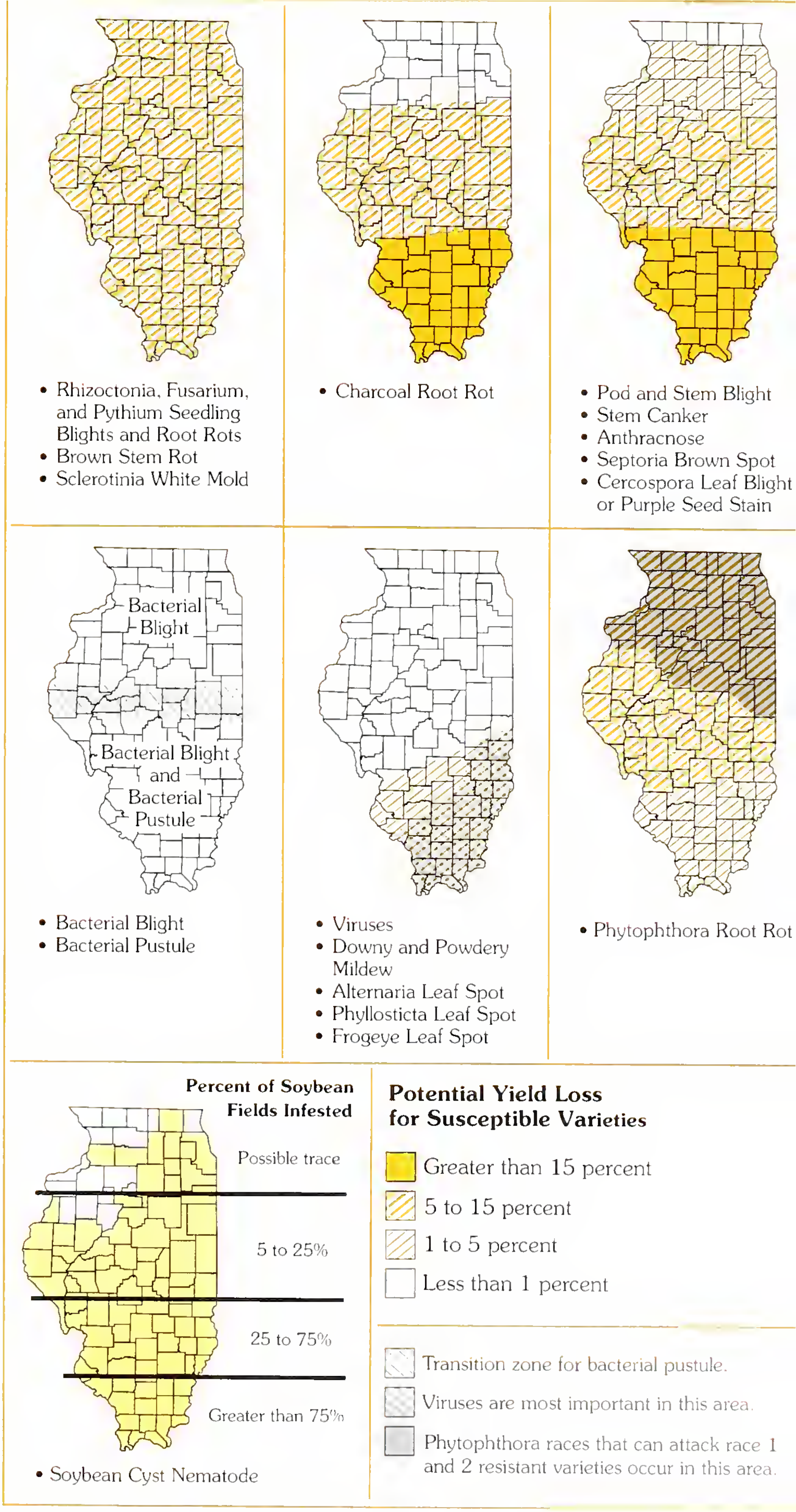


Figure 4. Potential disease risk areas for soybean production in Illinois.

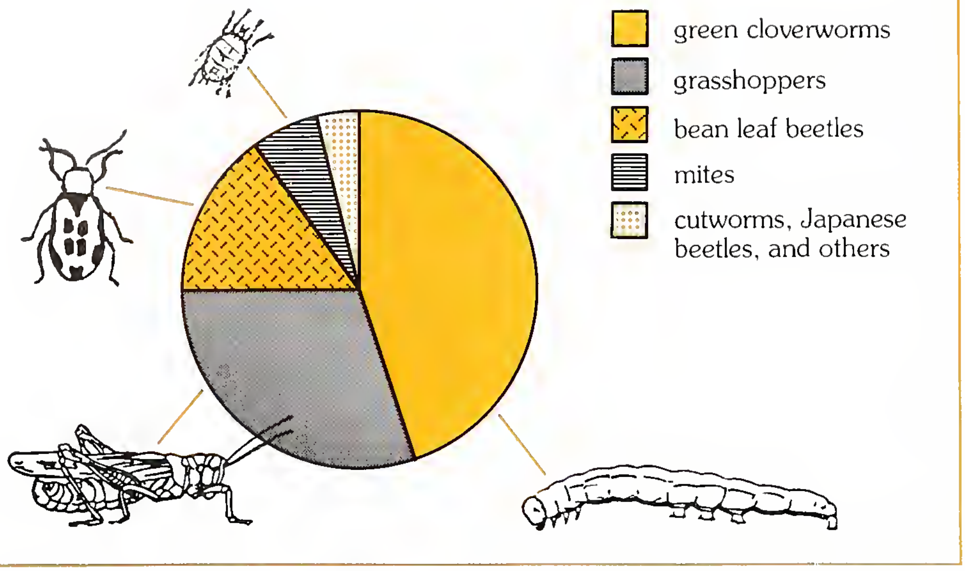


Figure 5. Percent of economic impact of the main soybean arthropod pests in Illinois.

Research by Jack Paxton on the control of Phytophthora root rot and by Dean Glawe on the biological control of soybean cyst nematode by fungi that attack the cysts are exciting examples of this work by plant pathologists at the University of Illinois. Glawe is trying to enhance the biological control exerted by the more than 70 species of fungi that he has found colonizing SCN in Illinois.

Planting disease-resistant varieties. The fourth major tool, the use of disease-resistant varieties, is the most simple, economical, and effective method of disease control. Research on developing disease-resistant varieties has been particularly successful. Today the Illinois soybean grower has high-yielding varieties with resistance to brown stem rot, bacterial pustule, powdery mildew, Sclerotinia white mold, 3 races of the soybean cyst nematode, several races of downy mildew and frogeye leaf spot, and 15 races of Phytophthora root rot.

Insects. Historically, four arthropod pests — green cloverworms, bean leaf beetles, grasshoppers, and spider mites — have accounted for 96 percent of the soybean acreage that has ever been treated with pesticides in Illinois (Figure 5). Other pests requiring occasional, but much more limited treatments are woollybear caterpillars, Japanese beetles, and cutworms. It should be noted, however, that although insect problems vary from year to year, in an average year less than one percent of the acreage planted to soybeans in Illinois is sprayed with insecticides to control all these pests. Overall annual losses from insects are estimated to average less than 3 percent of the crop.

The annual fluctuations in populations of soybean insect pests are due to climatic factors, inherent biological characteristics of the pest species, the unique interactions of the pest with the host soybean, and the action of natural enemies. Growers have little control over the first two factors; much can be done, however, to exploit the natural defenses of plants against insects and the effectiveness of natural enemies. If those natural control factors fail, then growers may resort to insecticides but only when pest populations increase beyond the EIL. Guidelines have been developed in Illinois to help growers identify pests and determine whether populations are approaching the EIL. The use of EILs as a guide for insecticide applications should maximize their economic benefits and minimize their impact on the natural enemies of insect pests.

Current research by Marcos Kogan and his co-workers at the University of Illinois is directed at understanding the natural defenses of the soybean against insect pests. Soybeans are inherently defended chemically against many pests. One inherent mechanism after an initial attack, for instance, is the production of defensive chemicals called phytoalexins. Recent experiments have shown that soybean plants that have been eaten by an insect at an early stage of growth are more resistant than undamaged plants to the same or to other insect species.

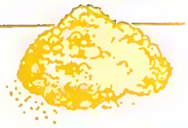
Study of the ecology of pests and their natural enemies should permit better forecasting of outbreaks. Improved forecasting is desirable especially because pest levels vary so much from year to year and from region to region.

Integrated pest management. It is rare that a soybean grower can use any one control method to manage the more than 20 diseases and the myriad of weed and insect pests that threaten productivity in Illinois. An integrated approach to pest management (IPM) is therefore essential for growers confronted by all these pests. Unfortunately, the economic relationships between pests, yield losses, and the control costs are poorly understood. Research on IPM should give tomorrow's soybean farmer the economic basis for sound decisions about pest control — the ability to reduce losses and increase profitability while helping to protect the environment.

Loyd M. Wax, USDA research agronomist and professor of agronomy, Barry J. Jacobsen, professor of plant pathology, and Marcos Kogan, entomologist, Illinois Natural History Survey and professor of agricultural entomology ☐

Miracle Crop of Many Uses

Soybean meal



Feed
Poultry feeds
Livestock feeds
Calf milk replacers
Protein concentrates
Pet foods
Fox and mink feeds
Fish food
Bee foods

Soy flour concentrates and grits
Edible uses
- Bakery ingredient
- Alimentary pastes
- Noodles
- Meat products
- Cereals
- Prepared mixes
- Food drinks
- Baby food
- Hypo-allergenic milk
- Confections
- Candy products
- Special diet foods
- Meat analogs

Industrial uses
- Adhesive
- Plywood
- Wallboard
- Insecticidal sprays
- Particle board
- Tape joint cements
- Linoleum backing
- Texture paints
- Nutrient
- Yeast
- Antibiotic
- Beer and ale

Soybean oil

Refined soy oil
Edible uses
- Cooking oils
- Mayonnaise
- Margarine
- Pharmaceuticals
- Salad dressings
- Salad oils
- Sandwich spreads
- Vegetable shortening
- Mellorine
- Medicinals
- Filled milks
- Coffee whiteners
- Creamers
- Liquid shortening

Technical uses
- Caulking compounds
- Core oils
- Disinfectants
- Electrical insulation
- Insecticides
- Fungicides
- Herbicides
- Pesticides
- Linoleum backing
- Oiled fabrics
- Printing inks
- Protective coatings
- Plasticizers
- Putty
- Soap
- Tin and terne plate oils
- Waterproof cement
- Wallboard manufacture

Soybean lecithin
Emulsifying agent
- Bakery products
- Candy products
- Chocolate coatings
- Pharmaceuticals

Nutritional uses
- Medical use
- Dietary use

Anti-spattering agent
- Margarine manufacture

Stabilizing agent
- Shortening

Anti-foam agent
- Yeast manufacture
- Alcohol manufacture

Dispersing agent
- Paint manufacture
- Ink manufacture
- Insecticides
- Rubber manufacture

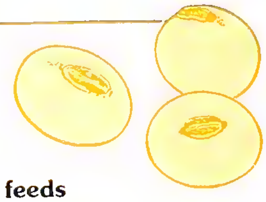
Wetting agent
- Cosmetics
- Pigments (paint)
- Calf milk replacers

Glycerol

Fatty acids

Sterols

Whole soybeans



Seed

Stock feeds

Baked soybeans

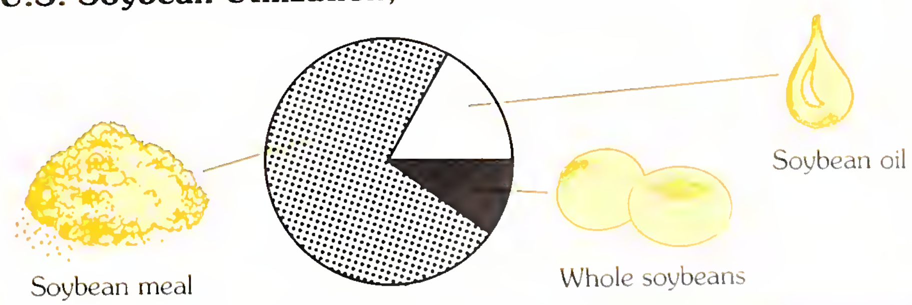
Full fat soy flour
Bread
Candy
Doughnut mix
Frozen desserts
Pancake flour
Pan grease extender
Pie crust
Sweet goods
Low cost gruels
Infant milk drinks

Roasted soybeans
Candy ingredient
Confection
Cookie ingredient
Cookie topping
Cracker ingredient
Fountain topping
Soy coffee
Soynut butter
Spite base
Dietary items

Soybean derivatives
Oriental foods
(Tofu, miso, and others)

Adapted from information provided by the American Soybean Association (1987).

U.S. Soybean Utilization, 1986 to 1987

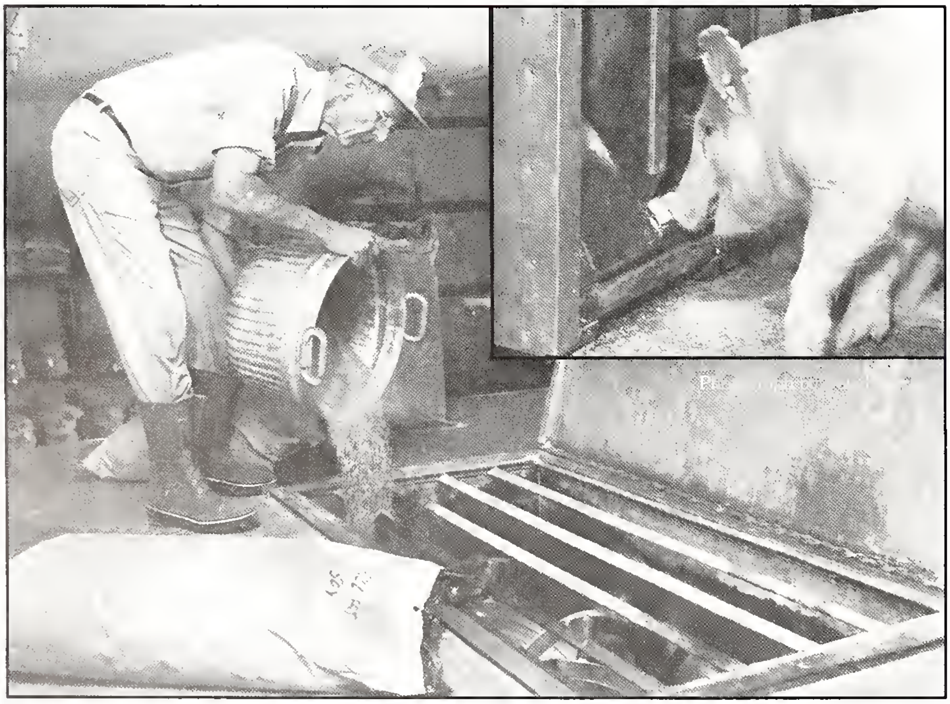


Soybeans in Human and Animal Nutrition

Soybeans and soybean products are important constituents of both human and animal diets. In human nutrition, the soybean is particularly valuable as a source of high-quality protein. When well-processed soy products serve as the main source of protein, their protein value approaches that of foods of animal origin. A variety of soy food products now contribute soy protein and oil to the diets of U.S. consumers.

Soy protein isolates and soy oil are used in manufacturing infant formulas. Currently infant formulas using soy isolates as the source of protein represent 15 percent of the infant formula market. When soy protein isolates are the sole source of protein for infants, they must be supplemented with the amino acid, methionine. Soy isolate-based infant formulas are particularly beneficial as substitutes for milk when infants have diarrhea or are allergic to formulas based on bovine milk. Soy also can be a primary cause of allergy, and the processing of soy-based foods can produce allergenic substances not detectable in the original products.

One of the most recently recognized nutritional benefits of soybean oil is its high content of omega-3 fatty acids. Recent scientific evidence indicates that the consumption of certain fish oils is associated with a decreased risk of developing coronary heart disease because of their high content of omega-3 fatty acids. Neither safflower nor sunflower oil contains omega-3 fatty acids, whereas 7 percent of the total polyunsaturated fat contained in soy oil is omega-3 acids. The polyunsaturated fats in cod liver oil and salmon oil contain about 20 percent.



A blend of ground yellow corn and extruded soybean meal form the basis of an excellent diet for growing and finishing pigs.

Of the several soybean products used to feed animals, soybean meal is unquestionably the most important. It is estimated that some 27.5 million short tons will be produced in the United States this year. About 7 million tons will be exported; most of the remainder will be consumed by poultry, swine, beef and dairy cattle, and sheep.

Over the past four decades, this protein-rich product has achieved global status as the standard of comparison for plant sources of protein used in feeding both swine and poultry. Soybean meal contains from 45 to 49 percent crude protein, which has excellent nutritional characteristics and digestibility. To achieve maximum growth efficiency, diets fed to poultry and swine must provide required amounts of essential amino acids. The cereal grains that form the basis for most diets fed to these species fail to provide adequate amounts of these amino acids. Adding soybean meal at the proper level to the formulation produces a diet that meets these requirements with only minor exceptions. The substitution of any other major plant-source protein will result in a diet with a deficiency of one or more amino acids.

Other soybean products are frequently found in animal feeds. Soy-protein concentrate is gaining prominence as an ingredient in the diet of pigs during the critical first 4 weeks after weaning. Recent evidence has shown that the performance of nonruminant animals fed cereal-based diets can be improved at certain stages of growth and reproduction by adding fat to the diet. Whole soybeans are an excellent source of digestible fat. Scientists are now investigating the potential for using properly processed, whole soybeans in diets for both swine and poultry.

Robert A. Easter, professor of animal sciences, and Mary Frances Picciano, professor of nutrition ☐

Soybeans in the Human Diet

Americans are consuming more soybeans and soybean products but might not recognize their shape or form! Whole soybeans, either dry mature or green, still represent a small fraction of their food market potential. Although in many parts of the world soybeans are eaten directly as food, in the United States only 3 to 5 percent of the soybeans produced are used for this purpose. Soybeans are primarily consumed as oil, margarines, and shortenings; another substantial portion is used in infant formulas.

Soy flours, concentrates, and isolates and other soy products are important functional ingredients in diverse foods, including processed meats, cereal products, snacks, salad dressings, whipped toppings, and frozen desserts. Studies by Barbara P. Klein and her co-workers in the Division of Foods and Nutrition and the Department of Food Science at the University of Illinois show that the emulsification, foaming, and texturization of soy proteins can be changed by other ingredients, as well as by the chemical and physical properties of the product itself. The taste and texture of extruded soy can be controlled to create a variety of unique foods by modifying either its proteins, formula, and composition, or the extrusion process.

Soy fiber is finding a place in high-fiber breads, cookies, muffins, and other commercially baked products with reduced calories. The ability of soy fiber and proteins to bind water improves shelf life and stability. Natural antioxidants in soybeans and soy flours can reduce lipid oxidation in many food products.

The natural beany flavor of soy is reduced by heat treatment, which eliminates enzymatic breakdown of the oil. Control of the enzymatic activity of lipoxygenase by processing or by genetic means improves the flavor of soy products. Although oils made from soybeans that are low in lipoxygenase are similar to those from common cultivars, the flavor and aroma of the meal are improved when enzymatic activity is reduced.

Home use of soybeans and whole soybean foods is increasing because of the ready availability in most supermarkets of tofu (soybean curd); soy sprouts; *tempeh*, *miso*, yogurt, and other fermented soy products; as well as frozen entrees and desserts containing tofu. Frozen green soybeans can be processed at home and may soon be available commercially. Recipes for whole soybeans developed at the University of Illinois can be obtained from the Cooperative Extension Service.

Soybeans will continue to appear in new food products as researchers and processors learn to take advantage of their unique physical, chemical, and nutritional properties. More soy products in our menus bring more variety to U.S. diets.

Barbara P. Klein, professor of foods and nutritional sciences ☐

This bean soup (1) and soy-flour products — crispy snack (2), bread (3), flour (4), cookies (5), pancakes (6), weaning food (7), and meatless patties (8) — are just a few of the many tasty, nutritional foods that can be prepared from soybeans.

Utilization of Whole Soybeans as Human Food

A soybean contains almost 40 percent high-quality protein, as well as unsaturated fat, carbohydrates, fiber, minerals, and vitamins. At present, there is no other protein source that can be produced so economically and in such mass quantities. Another benefit of the whole soybean is that it can be prepared to have a very bland flavor. This quality is desirable when creating new foods, but it is most important when blending soy into traditional foods because they can be fortified with soy to greatly improve their protein and other nutritional qualities without altering their basic acceptability.

The University of Illinois became involved in the commercial utilization of whole soybean foods back in 1969, when only a few foods prepared from whole soybeans were available in the United States. These consisted largely of a few imported products sold in ethnic food stores. In a limited survey of the soybean foods produced in this country, researchers at the University of Illinois found that most were prepared from oil extracted by a solvent and that a few were refined products from oil-free meal.

At that time, only two organizations were actively engaged in utilization research on whole soybean foods. Work at Cornell University concentrated on developing liquid soy beverages, while the U.S. Department of Agriculture Northern Regional Laboratory at Peoria was developing a powdered soy beverage and also working on a dry corn-soy-milk product for the Food For Peace (PL480) program. Quite a number of processes for a soy milk or soy beverage had been described or patented earlier in this century but were all found to have some undesirable characteristics.

The basic concept: Control the processing. Research on soy-based foods at the University of Illinois was started in January 1970 by Lun Shin Wei, Marvin P. Steinberg, and Alvin I. Nelson in the Department of Food Science. This group envisioned that soybeans could be processed like other seeds or dry, garden-type beans. Their basic concept for processing soybeans required the control of three major processing factors: the lipoxygenase enzyme, the antinutritional agents, and the texture of the soybean.

The primary considerations were flavor and nutrition. As with most enzymes in vegetable tissue, lipoxygenase can be easily inactivated by blanching or cooking before it produces an off-flavor or off-color. Proper blanching or cooking also destroys the trypsin inhibitors and other antinutritional factors. Sodium bicarbonate in concentrations of 0.05 to 0.5 percent was found to be a very effective tenderizer of bean tissue for specific human food products: it reduces by one-half the cooking time required to reach a given tenderness.

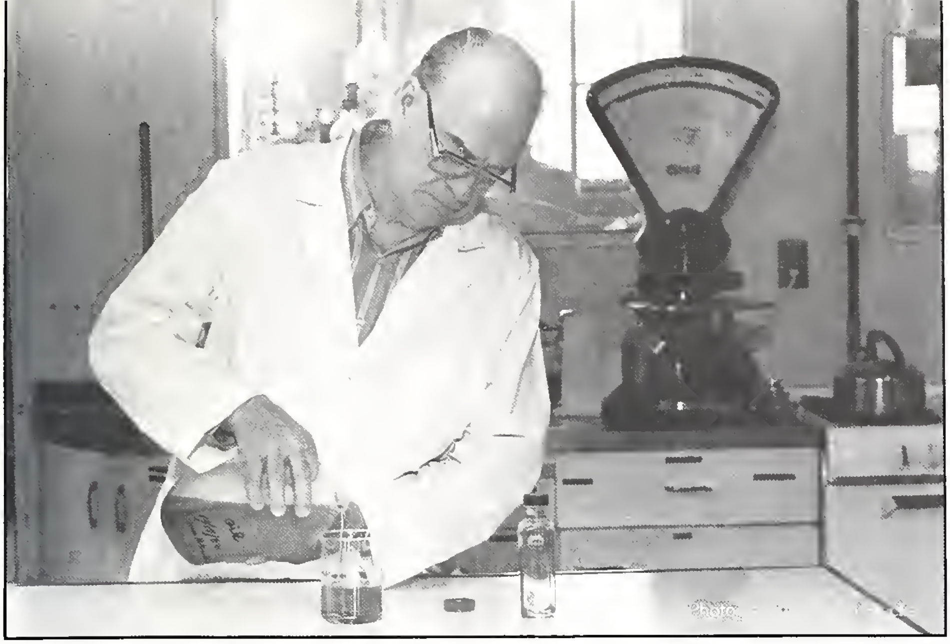
Current value-added studies and processing and product research. The current utilization project involving the International Soybean Program (INTSOY) and the Department of Food Science is under the leadership of Nelson and has been in operation for about three years. Funded mainly by the U.S. Agency for International Development, this project encompasses both value-added studies and processing and product research. The work on these two complementary program areas includes: extrusion processing, extrusion and expelling of oil and cake, soy-milk and analog processing, utilization in the home and village, and development of immature green soybeans as a commercial product.

Extrusion processing. The heat for extrusion cooking is generated by friction. This method of processing, therefore, requires a motor of substantial horsepower. The extruder used in current studies, for instance, is an Insta-Pro 2000R, which has a 75-horsepower electric motor and processes food products containing relatively low moisture. This extruder will raise the temperature of the product from ambient to between 275° and 300°F (135° and 148.8°C) in about 25 seconds.

Extrusion cooking is ideally suited for combining soybeans and cereal grains into excellent finished products. Snack foods containing about 17 to 18 percent high-quality protein have been prepared by using 30 percent dehulled raw soybeans and 70 percent whole raw corn.

Two other very good extruded products are soy-rice and soy-potato-corn snacks. Another is a bean soup mix, which contains a high percentage of soybeans, as well as dry garden beans and wheat flour. This extruder can effectively produce other high-quality soy and cereal products.

Extrusion-Expelling. A processing method that provides continuous, mechanical expression of oil from soybeans is an important objective of developing countries and is also of considerable interest in the United States



Alvin I. Nelson, leader of the utilization project on soybeans and soy-food products conducted by INTSOY and the Department of Food Science, evaluates a beaker of soy oil.

as a value-added operation. Raw, whole, ground soybeans are discharged as a semifluid from the extruder when they reach a temperature of about 275°F (135°C). This hot extruded material contains free oil. When passed through a mechanical oil expeller, this oil can be easily expressed and separated from the cake. The total heating time for the two processes is less than a minute.

Both the oil and cake are of high quality. The oil contains from 7 to 8 percent omega-3 fatty acids, the widely publicized component found in fish oil, and is more stable than highly refined oil from solvent extraction. With only simple degumming, it is ideal for cooking and other uses. Considerable work is necessary, however, to thoroughly evaluate all aspects of this soybean oil. The cake, which contains 50 percent protein and 5 percent oil, has been tested in bakery products and other items requiring protein fortification. It also makes an excellent animal feed.

Soy milk and dairy-type analogs. In 1976, Nelson, Wei, and Steinberg were issued a U.S. patent for a soymilk process. This process was unique because it included all of the blanched soybeans in the final soy milk, resulting in very high yields of finished products. The flavor was very good, but the mouthfeel was often chalky.

INTSOY researchers are now concentrating on a high-yielding process for the preparation of a soy milk with excellent mouthfeel and flavor. This effort incorporates some of the features of the earlier patented process but also includes an extracting step that eliminates the chalkiness.

Significant progress has been made on devising an economical process for soy milk, soy yogurt, and soy ice cream. A small tofu manufacturing plant is being used to improve yields and to reduce or eliminate the beany flavor in the final product.

Home and village utilization. In the mid-1970s, INTSOY researchers spent considerable time and effort on improving home methods for soy product utilization in developing countries. Many homemakers were extremely interested in using soybeans because they were continually hearing about the bean's remarkable nutritional qualities. Many were discouraged, however, by the poor flavor and the long cooking time required to properly tenderize the finished product.

By following basic soybean processing concepts, INTSOY researchers developed a system of crushing or breaking dry, whole beans into many small fragments and then cooking them in boiling water with a small amount of sodium bicarbonate. This procedure not only eliminates the beany flavor, it also very rapidly hydrates, cooks, and tenderizes the small soy fragments.

The bean particles are first cooked for 15 minutes; then they are cooked for another 15 minutes after diced potatoes, sweet potatoes, squash, carrots, or other diced vegetables have been added. A total of only 30 minutes, therefore, is required to completely cook the product. Whole soybeans must be cooked about three hours to obtain an acceptable texture. This method is already being used in homes and small communities in a number of developing countries.

Frozen green soybeans. Work on green soybeans during the last two years has focused on problems with harvesting, shelling, cleaning, and blanching the green immature seeds. The frozen prepared product has been sampled by at least 100 people, and reactions have always been positive. The Joan of Arc and Green Giant divisions of Pillsbury will cooperate this year to solve the problems that remain.

Because of their high protein and excellent taste, green frozen soybeans offer considerable market potential in the United States. They do not compete with other soy products, and they are an alternative early season cash crop for farmers. Commercial development of frozen green soybeans on a national scale will require soybean production on many thousands of acres for a harvest of immature beans. This additional use of the soybean would help reduce the overall soybean surplus.

Alvin I. Nelson, professor emeritus, food science and leader, INTSOY Utilization Program, and Lun Shin Wei, professor of food science ☐

Soybean Oil to Burn

Domestic production of petroleum has been declining in recent years, and we are again becoming heavily dependent on imported petroleum. What if petroleum imports were interrupted? How would farmers keep their diesel-powered tractors and combines rolling through critical seasons? The answer may be in their own fields in the form of the oil from their soybean crops.

We know that soybean oil can substitute for diesel fuel, but questions arise. Is there enough soybean oil to supply diesel fuel needs? How much would soy-oil fuel cost? Would soy-oil fuel damage engines? Research is providing answers to these questions.

Engines have much bigger appetites than humans and animals. Typically, oil from the entire U.S. soybean crop could replace only 18 percent of U.S. diesel fuel needs. About 93 percent of the crop would be needed to replace all of the diesel fuel used in agricultural production. Thus, even partial adoption of soy-oil fuels could easily consume surpluses of soybean oil, but engines cannot consume surpluses of soybean meal, which comprises 80 percent of the soybean. If soy-oil fuel is to become a reality, geneticists may need to redesign the soybean plant to produce more oil and less meal.

At the current wholesale price of about $1.30 per gallon, soy oil is much more expensive than diesel fuel. If petroleum supplies were interrupted, however, petroleum prices could rise quickly to equal or exceed the price of soybean oil.

Soybean oil is too viscous or syrupy to be used as a whole fuel in modern diesel engines. Blends containing 25 percent or less of soy oil work well in diesel fuel but produce increasingly larger deposits of carbon in engines that are in constant use. Ironically, the polyunsaturates in soybean oil that are good for the human diet are a bad diet for engines: they promote the formation of carbon deposits in engines that use soy oil as fuel. Chemical modification of soy oil for fuel use, however, appears promising. Soy oil in chemi-

Changing Markets for U.S. Soybeans

The markets for U.S. soybeans and soybean products have significantly changed over the past 14 years. In general, the total market grew rapidly in the 1970s and early 1980s and then stagnated or actually declined over the past 4 to 5 years. Within that general trend, there have also been shifts in markets.

The growing markets from 1972 through 1980 caused generally high soybean prices, although annual variations in U.S. yields, along with the production of competing commodities around the world, led to substantial variation in price during the growth period. Soybean acreage expanded rapidly in response to market growth and price incentives. Acreage peaked at 71.4 million acres in 1979, up 52 percent in comparison to 1972.

Rapid increases in production, a slowdown in growth, the accumulation of stocks, and low prices led to acreage declines of 10 million acres by 1986. In spite of declining acreage and production, soybean stocks have continued to accumulate, and prices have declined significantly. The monthly average price of soybeans has been under $6.00 per bushel since December 1984.

Strong domestic use of soybean meal. Domestic use of soybean meal grew rapidly during the 1970s. By 1980, it expanded to 19.2 million tons and since then has remained at high levels. The increase in domestic use of meal was associated with expanding livestock and poultry production as a result of strong consumer demand. There was also a significant increase in the rate of soybean meal feeding per animal in the mid-1970s. Domestic soybean meal use exceeded 19 million tons in the 1984-85 and 1985-86 marketing years and was a record 20.5 million tons in the 1986-87 marketing year.

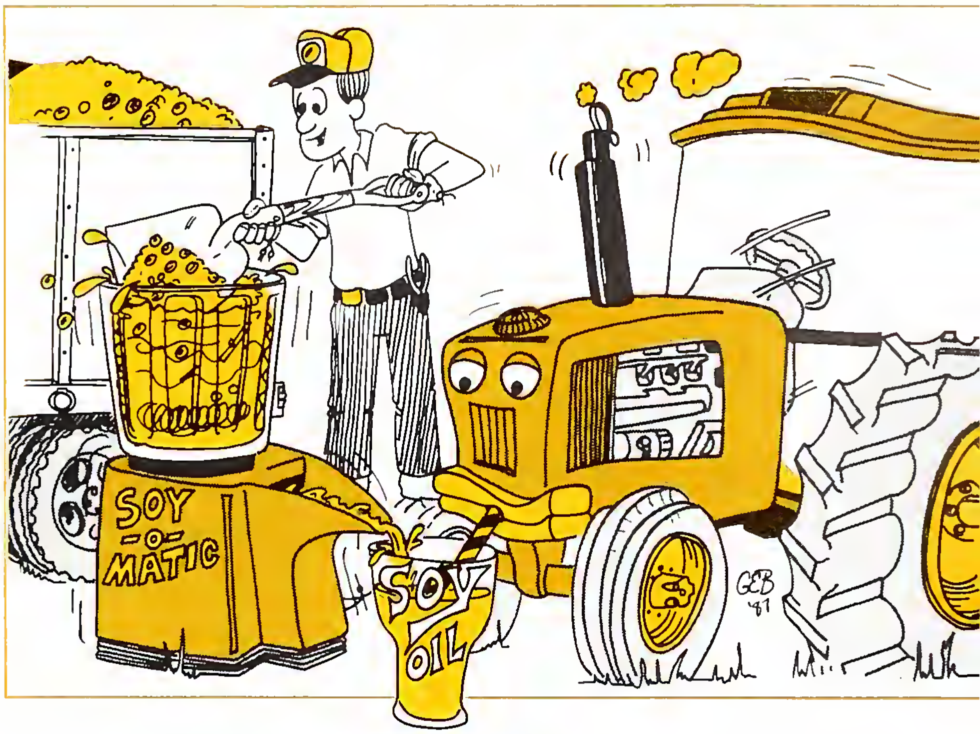
Based on U.S. Department of Agriculture estimates of meal feeding by type of livestock, poultry accounts for the largest use of meal. Poultry consumed an estimated 6.7 million tons of meal in the 1975-76 marketing year and 8.6 million tons a decade later. Consumption by poultry in the 1986-87 marketing year will probably exceed the record of 9 million tons established in the 1982-83 marketing year. Meal feeding to hogs and cattle has been relatively stable. Consumption by hogs has ranged from 4.9 to 6.0 million tons annually; cattle have consumed from 3.0 to 3.9 million tons. Poultry may account for nearly half of the domestic use of meal in the 1986-87 marketing year.

Higher domestic oil consumption. Domestic soybean oil consumption increased sharply in the 1975-76 marketing year and since then has been trending higher. Oil use for that year totaled 7.9 billion pounds, compared to the average for the previous 6 years of 6.6 billion pounds. By the 1985-86 marketing year, domestic

cal reaction with alcohol produces an ester, a fuel that is like diesel in viscosity and ignition properties. Alternatively, through a process called pyrolysis, soy oil can be chemically converted by heat to hydrocarbons that are similar to those in ordinary diesel fuel. Research on these chemically modified soy-oil fuels is currently conducted by Lester Savage in the Department of Mechanical Engineering and Carroll E. Goering in the Department of Agricultural Engineering at the University of Illinois.

Soybean oil surpluses are a current farm problem. Diesel fuel shortages are a potential problem. Development of a soy-oil fuels program could help solve both.

Carroll E. Goering, professor of agricultural engineering ☐



soybean oil consumption had increased to 10.1 billion pounds. Use was estimated at 10.75 billion pounds for the 1986-87 marketing year.

Soybean oil accounted for 56 percent of the total domestic consumption of edible fats and oils in the 1983-84 marketing year. Two years later that market share had grown to 71.6 percent. During the 1985-86 marketing year, 99.6 percent of domestic soybean oil use was in edible products, with only 0.4 percent used in industrial products.

Of the total used in edible products, 46.8 percent was used as salad or cooking oil, 34.4 percent was used as baking or frying fats, and 17.3 percent was used in margarine. Soybean oil had 78.5 percent of the salad and cooking oil market, 61.8 percent of the market for baking and frying fats, and 84.9 percent of the margarine market.

The generally high level of domestic meal consumption and increasing level of oil use have kept the level of domestic soybean crush high. The largest crush, 1.123 billion bushels, was in the 1982-83 marketing year. Estimates for the 1986-87 marketing year were for a new record crush of 1.18 billion bushels.

Exports have been more variable. From 1973 through 1977, exports of U.S. soybeans averaged 520 million bushels per year. Exports jumped the next year to 700 million bushels, grew to a peak of 929 million bushels in the 1981-82 marketing year, and then declined to 598 million bushels in the 1984-85 marketing year. Exports rebounded to 740 million bushels the following year and are estimated at 770 million bushels for the 1986-87 marketing year.

The growth in soybean exports was associated with a rapid increase in world demand for protein feeds. The decline in soybean exports since the 1982-83 marketing year has been the result of increased soybean production in other parts of the world, particularly in South America, and a decline in world protein demand. Soybean production outside of the United States increased from 1.25 billion bushels in the 1982-83 marketing year to 1.4 billion bushels the following year. Production for the 1986-87 marketing year is projected at 1.7 billion bushels, a 36-percent increase in 4 years. Fifty-three percent of the increase has been in South America.

South American meal has been substituted for U.S. meal in Europe, and production of major oilseeds in countries other than the United States has increased by 23 percent since the 1979-80 marketing year, which marks the beginning of the most recent period of decline in oil exports. Oilseed production in the United States in 1986 was about equal to that of the 1979-80 marketing year. For the 1986-87 marketing year, meal exports were estimated at 7.4 million tons; oil exports are projected to be only 1.1 billion pounds.

What next? The period from 1976 through 1980 represented the third major growth stage in U.S. soybean production and marketing in the past 24 years. The period since then, particularly the last two seasons, has been one of retrenchment. Is the stage set for another growth period? If so, that growth will have to come from a resurgence in protein demand outside of the United States.

Darrel Good, professor of agricultural economics ☐

Soybeans in International Agriculture

Soybeans play a major and growing role in the world food system. World production of soybeans increased fivefold from 1950 to 1985, whereas world corn and wheat production only tripled. Yet the importance of soybeans is frequently misunderstood or overlooked because their multiple uses make soybeans an "invisible" contributor to world diets. Soybeans have a long history of use in traditional Asian food products, but currently most of the world's soybeans are crushed to provide protein meal for animal feeds and edible oil products like margarine. This article looks at how and why soybeans have become more important in world agriculture and international trade.

World soybean production. Soybean cultivation originated in the North China Plain and spread throughout East and Southeast Asia. Today, China is still a major producer of soybeans, accounting for about 10 percent of world production (Figure 1). Other countries in Asia produce only minor quantities.

Large-scale, commercial cultivation of soybeans in the United States began in the 1920s, when processing plants were first established in the Midwest. After World War II, production expanded rapidly, and the United States became the leading world producer in 1955. At present, the United States accounts for almost two-thirds of the world's total production (Figure 1). Soybeans are the fourth largest source of U.S. farm income and provide one-quarter of farm income in Illinois.

Since 1970, production of soybeans has expanded significantly in four Latin American countries: Argentina, Brazil, Paraguay, and Uruguay. Like the United States, these countries have abundant land and favorable growing conditions for soybeans. Production has grown most rapidly in Brazil (Figure 2), which now harvests 15 to 20 percent of the world's supply, and in Argentina, which provides 5 to 10 percent (Figure 1).

Yields and production systems for soybeans vary widely around the world. Among the major producers, the United States and Argentina have the highest average yields of about 2 metric tons per hectare (30 bushels per acre). Lowest average yields, about 1 ton per hectare (15 bushels per acre), are found in China. In the United States soybeans are cultivated on big farms with large amounts of chemical and mechanical inputs; Asian farmers use much more labor and fewer chemicals. Yields are lower in Asia partly because less fertilizer and fewer pesticides are used and because growing conditions are less favorable.

All major producers have experienced modest, but steady improvements in yield over time. Growth in soybean production, therefore, is largely due to increases in cultivated area in the Western Hemisphere. In some countries, however, expanding the area cultivated in soybeans has brought poorer land into production. Producing on poorer land has reduced potential yields, and offset, to some extent, the yield-increasing effect of technological change.

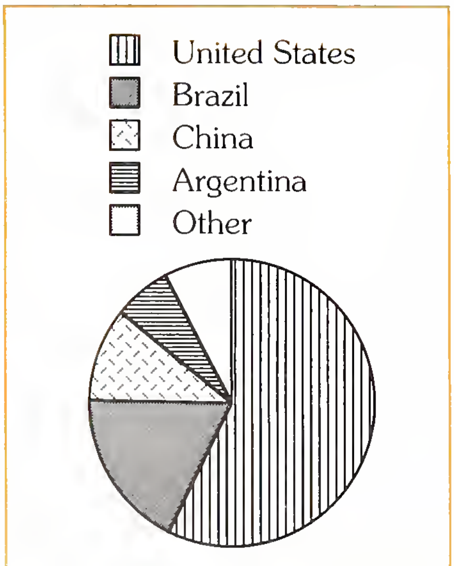


Figure 1. Average Share of World Soybean Production, 1983 to 1985.

World soybean consumption. Over 80 percent of world soybean production is crushed to provide meal and oil. The soybean is the single largest source of supply in both protein meal and edible oil markets, providing 30 percent of the world's edible oil and 50 percent of world supply of protein meal for animal feeds. The soybean has this large share of the world market for protein meal because its ratio of protein to oil is highest among all oilseeds. The soybean also has high-quality protein compared to other oilseeds.

The pattern and growth of soybean product consumption are influenced by changes in diets as incomes rise. People all over the world consume fewer starchy staples and more oils and meats as incomes grow. Animal products provide only 5 to 10 percent of the calories consumed in the poorest countries, but 35 to 40 percent in the wealthiest nations. As world income increases, demand for oils and meats grows, causing growth in the demand for soybeans.

Because income is a major determinant of soybean meal and oil consumption, it is not surprising that high-income industrial countries are the largest consumers (Figure 3). The European Economic Community (EEC), Japan, and the United States account for two-thirds of world soybean meal consumption and one-half of world soybean oil con-

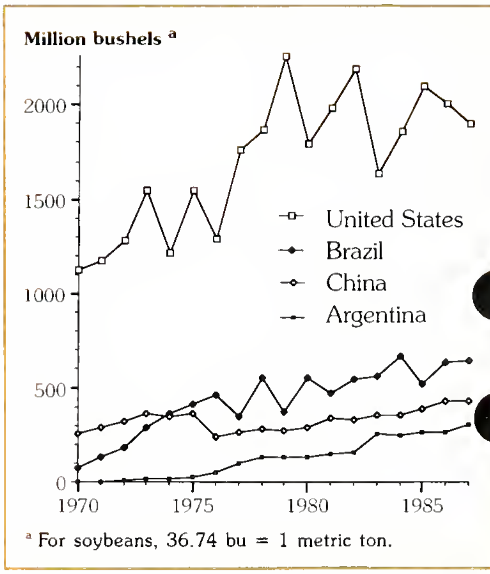


Figure 2. Soybean Production by Country, 1970 to 1987.

sumption. These industrial countries currently consume most of world supply, but recent growth in demand for soybean products has been greatest in less developed countries because incomes are growing most rapidly there. The share of world soybean oil consumption held by less developed countries has increased from 40 to 50 percent during the last 10 years, and their share of world soybean meal consumption has also increased slightly.

Demand for soybean meal is growing most rapidly in newly industrializing countries. South Korea provides an interesting example of how changes in diets with rising incomes are powerful determinants of soybean demand. From 1960 to 1980, per capita income in South Korea tripled from $500 to $1,500. As a result, meat consumption increased from 12 to 40 kilograms per capita. To satisfy increased meat demand, livestock production and feed use also increased rapidly, causing soybean meal consumption to increase from zero to 300,000 tons in only 20 years.

The use of soybeans for food products is a very small part of total use in most countries, but there are some exceptions. For instance, from 1983 to 1985, Indonesia used 92.9 percent as food; China, 73.8 percent; and South Korea, 35.9 percent. Substantial amounts of soybeans are consumed directly in food products, like tofu (bean curd) or *tempeh* (fermented beans) in Asian countries. Food use of soybeans in Nigeria has grown rapidly because soybeans are substituted for local beans in traditional food products.

International trade of soybeans. Growth of trade in soybeans and soybean products has been more rapid than that of world production. Total trade of soybeans expanded sixfold from around 5 million tons in 1960 to almost 30 million tons in the early 1980s. In contrast to feed grains or meats, world trade in soybeans and soybean products is relatively unrestricted, allowing rapid growth. The protection that some countries give their domestic crushing industries, however, influences whether soybeans are traded as raw beans or as oil and meal.

Countries in the Western Hemisphere that dominate world production also dominate world trade. The United

Table 1. Shares of World Trade Held by the United States and Its Main Competitors [a]

Countries/Regions	'68-'72	'73-'77	'78-'82	'83	'84
	percent				
Whole soybeans					
United States	92	80	84	86	76
Argentina	0	1	9	5	12
Brazil	3	16	3	5	6
China	4	2	1	1	3
Soybean meal					
United States	67	46	37	29	22
Argentina	0	1	3	7	12
Brazil	12	32	39	38	37
Northern Europe [b]	17	17	18	19	18
Soybean oil					
United States	62	37	32	21	25
Northern Europe [b]	21	32	22	18	17
Brazil	1	16	25	29	23
Spain	6	5	12	12	11
France	2	5	4	4	3

[a] *Sources:* Food and Agriculture Organization of the United Nations, U.S. Department of Agriculture.
[b] Includes Belgium, the Netherlands, Denmark, and West Germany.

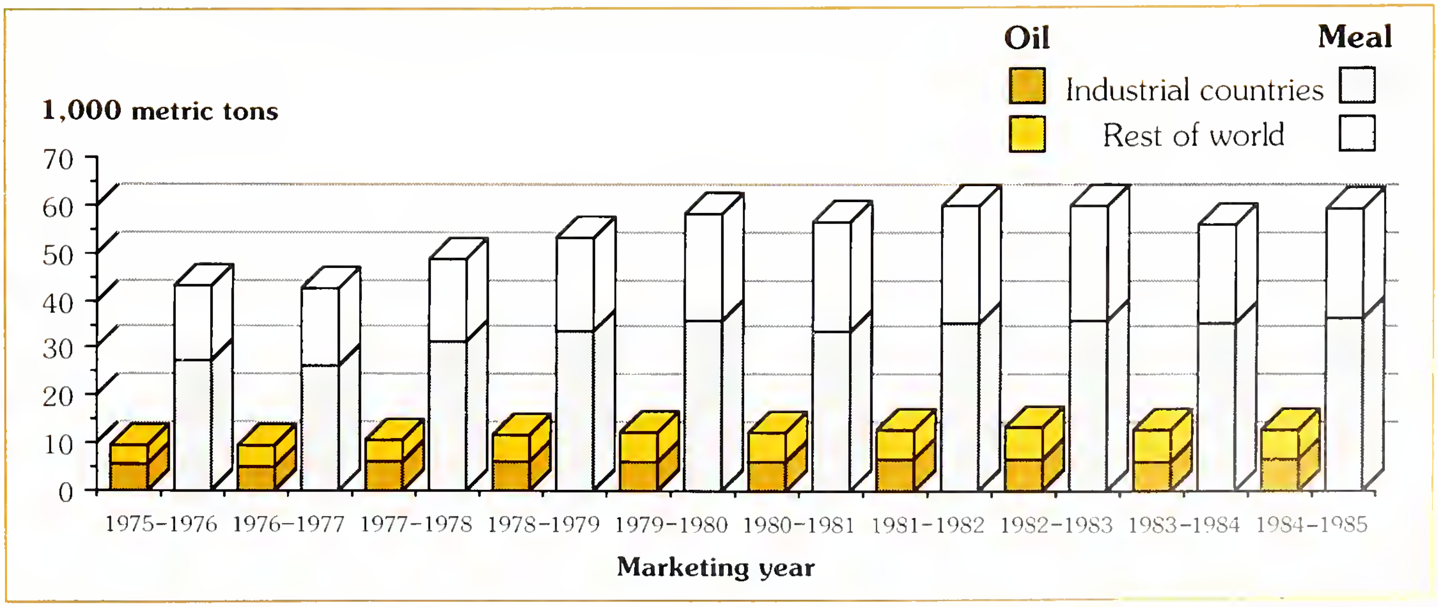


Figure 3. World Consumption of Soybean Oil and Meal.

States is the principal exporter of soybeans and completely dominated the market before 1972 (Table 1). Currently, the United States accounts for over 80 percent of all whole beans traded internationally and over 20 percent of soybean meal and oil. During the last 15 years, Argentina and Brazil have emerged as major competitors in soybean product markets (Table 1), now supplying 45 percent of the exported soybean meal and 25 percent of the exported soybean oil. Brazil, unlike the United States, exports more soybean products than whole beans. Incentives provided by the Brazilian government to domestic crushers make exporting these products more profitable than exporting whole beans.

The EEC and Japan are major importers of beans from the United States for their domestic crushing industries (Table 2). Japan protects its domestic soybean processors by confining imports to whole beans. Domestic vegetable oils in the EEC are protected so that some processors benefit from importing whole beans and selling both oil and meal. But this processing does not fulfill the demand for soybean protein meal, so imports are needed. In fact, most soybean meal exports go to the EEC and other European countries (Table 2).

Soybean oil imports from the United States flow to a different set of countries. Oil is primarily purchased or received as food aid by less developed countries in South Asia (India, Pakistan, and Bangladesh) and in Latin America (Chile, Colombia, and Venezuela). Because demand for oil is large relative to meal in these countries, there is no need to import raw beans for crushing.

The share of soybean imports held by less developed countries, particularly their share of soybean protein imports, has increased over time (Table 2). This trend should continue. With rising incomes, many less developed countries will experience rapid growth in demand for meat and require increasing amounts of feed grains. South Korea again provides a good example because its imports of soybeans and soybean products on a soybean equivalent basis grew from zero in 1965 to over 1 million tons in 1985.

World trade is very important to U.S. soybean producers. Almost two-thirds of the crop is exported, and it accounts for one-fifth of the value of U.S. farm exports. The United States has been fortunate to adapt the soybean successfully to its agro-climatic conditions to become the world's largest producer and exporter of soybeans. After World War II, the United States helped meet the growing demand for edible oils and protein feeds in industrial countries. To continue its leading role, the U.S. industry will need to understand changes in the structure of world production and consumption of soybeans. Growing demand for oils and meats in less developed countries and wider acceptance of new and traditional soy food products ensure that soybeans will continue to play an important role in agricultural trade and world diets.

Laurian J. Unnevehr, assistant professor of agricultural economics, Jane E. Gleason, INTSOY agricultural economist, and Harold E. Kauffman, director, INTSOY, and professor of international agriculture ☐

Table 2. Percent of Total U.S. Exports by Country or Region, 1973 to 1984 [a]

	Whole soybeans				**Soybean meal**			
	'73-'77	'78-'82	'83	'84	'73-'77	'78-'82	'83	'84
	percent							
Country/Region								
EEC	46	44	38	34	60	53	62	40
Japan	21	18	20	22	3	3	0	0
USSR	2	3	2	0	0	0	0	0
Asia, Other	10	12	14	14	1	4	6	18
Europe, Other	12	15	19	18	23	23	12	10
Latin America	2	4	6	10	6	10	14	20
Other	7	4	1	2	7	7	6	12
	100	100	100	100	100	100	100	100
Type of economy								
Less developed	8	13	18	22	7	15	20	38
Developed	87	81	76	74	76	67	71	53
Planned	5	6	6	4	17	18	9	9
	100	100	100	100	100	100	100	100

	Soybean oil			
	'73-'77	'78-'82	'83	'84
	percent			
Country/Region				
Europe	7	2	0	0
East and Southeast Asia	7	7	2	2
South Asia	29	51	32	45
West Asia	16	5	1	2
Latin America	28	34	36	41
Other	13	1	29	10
	100	100	100	100
Type of economy				
Less developed	77	86	80	95
Developed	13	7	2	3
Planned	10	7	18	2
	100	100	100	100

[a] *Source:* U.S. Department of Agriculture

Soybean Production Research

Numerous aspects of soybean production are studied annually in the College of Agriculture — development of new varieties, tillage alternatives, seeding rates, row spacings, intercropping, pest and production problems, and irrigation. Yet, this is only a partial listing of the topics that, for lack of space, cannot be fully addressed here.

Research projects can yield useful information that allows soybean production to be more successful, more profitable, or both. Here, we summarize two applied studies that deal with issues which at some time relate to concerns of virtually every producer in Illinois.

When to replant. Numerous problems may be encountered by soybeans as they begin to germinate and grow in the spring. Poor seed quality, excessively deep planting, soil crusting, or numerous other factors can produce poor stands. And a less-than-desirable stand can be a major concern to growers. The option, then, of replanting a deficient stand is many times considered; but profits from replanting are often minimal or nonexistent.

During the 1981 through 1985 growing seasons, a series of experiments was conducted to evaluate the "yield-compensating ability" of soybeans when normal or full stands were not achieved. Results of the experiments clearly demonstrated that soybean plants can compensate for missing plants in the field by developing additional branches, which contribute to yield and compensate for missing plants in a less-than-full stand.

When short-statured, determinate type varieties were compared to larger, indeterminate varieties, which are most frequently grown in the Midwest, the degree of compensation for yield in deficient stands was found to be the same. From the results of those experiments, it can be concluded that, for soybeans that emerge poorly, the growth habit should not be a major consideration in deciding to replant.

If soybean emergence is poor enough, the need to replant is certain. Visual impressions of a less-than-perfect stand, however, tend to overestimate the severity of the problem. For that reason, needless replanting does occur and fails to increase income to the grower. To minimize overreaction by producers, a simple method of field sampling has been developed that produces a reliable estimate of the degree to which a stand is reduced. Random observations at 50 locations in the deficient stand area are required to determine the extent of the reduction.

Results of stand-reduction experiments can be used to estimate what the yield loss will be at various stand-reduction levels. The variation of plant density in remaining row sections is also considered. A summary of the impact that stand reductions and plant number-per-foot-of-row have on the percent of potential full soybean yield is presented in the table.

Using the method developed to measure stand-reduction levels, coupled with knowledge of the yield potential associated with reduced stands, growers can estimate the portion of a full yield that a deficient stand may produce. If the reduction in yield potential is great enough, replanting will be justified. Stand-loss levels in the range of 30 to 40 percent result in relatively small losses in yield, which in most cases may not justify replanting. The cost of replanting obviously includes a cost for seed, labor, and equipment but also includes a loss in overall yield potential due to delayed seeding. The cost of keeping a less-than-perfect stand, in addition to possibly some loss in yield potential, may include added costs for weed control to ensure that gapped areas in the stand do not fill up with weeds.

A detailed explanation of how to evaluate stand reductions and make a most profitable replanting decision is available in a free publication: Circular

Percent of Full-Yield Potential for Soybean Fields with Deficient Stands

Stand reduction, percent	Plants per foot of 30-inch row [a]		
	8	6	4
	percent of full-yield potential		
0	100	97	95
10	98	96	93
20	96	93	91
30	93	90	88
40	89	86	83
50	84	81	78
60	78	75	73

[a] Plants per foot of row in sections without gaps.

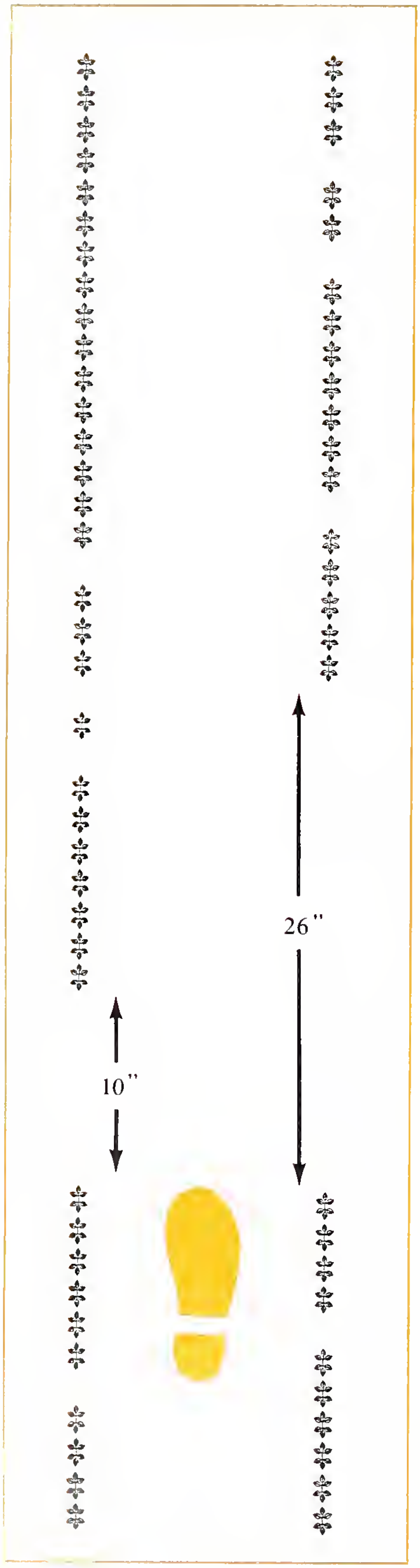


Figure 1. Observing gaps in a soybean stand by using the Boot-Toe Method. In this illustration, only the 26-inch gap would be recorded. Each ⚘ represents a seedling.

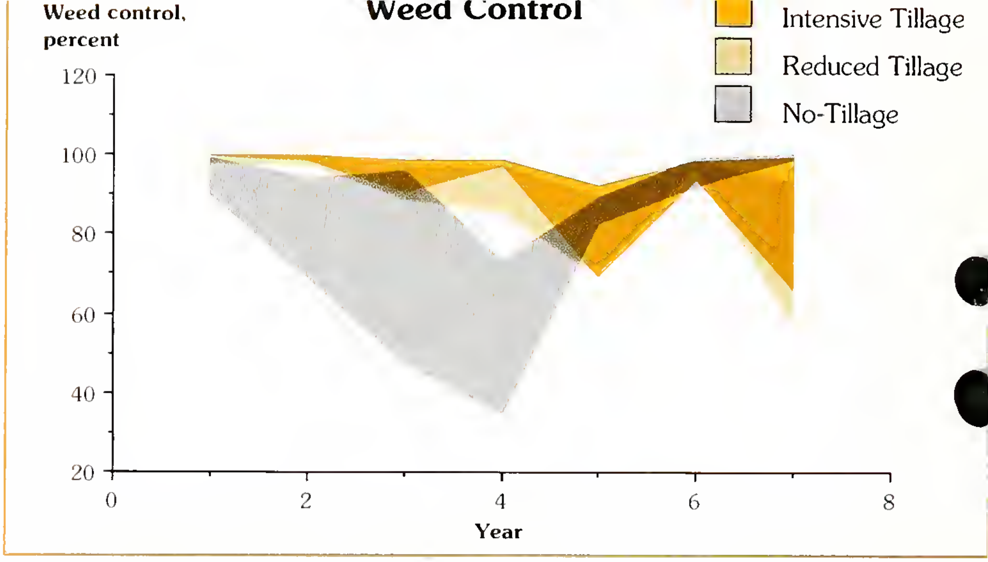


Figure 2. Weed control range (average of broadleaf and grass control) achieved with each level of tillage includes data from preplant-incorporated, preemergence, and postemergence weed control alternatives. Beginning in year 5, an early preplant application of Roundup was added to the no-tillage weed control program.

1265 *Soybean Replanting Considerations for Maximizing Returns* can be obtained at county Extension offices or from Agricultural Publications, 54 Mumford Hall. The step-by-step procedure contained in the circular leads the grower through the process of evaluating a poor stand and considering the profit potential of a less-than-perfect stand versus one that might be obtained with replanting (Figure 1).

Conservation-tillage production systems. Although conservation tillage of corn and soybeans reduces soil erosion, it also alters all other aspects of production. The basic concept of conservation tillage, in which crop residue is left on the soil surface, is in direct conflict with several established pest management practices. Notably, most herbicides used in corn and soybean production are now incorporated; row cultivation is also used to help control weeds; and plowing under the plant residue destroys several insect species and disease organisms that otherwise overwinter.

Whatever tillage system is used, adequate weed control is essential for profitable production of corn and soybeans. Current weed control technology uses cultural methods and chemicals, either singly or in various combinations, to prevent establishment of weed seedlings and to eliminate weeds that survive initial control measures.

With conservation tillage systems, much greater emphasis is placed upon using herbicides that do not depend on tillage for incorporation and upon controlling the weed species that escape the options for control that are currently available at planting time. Also, the effect of environmental factors on pesticides varies among tillage systems; and this may affect the efficacy, economics, and environmental impact of chemical pest control.

Illinois corn and soybean producers are interested in alternative tillage and weed control combinations to reduce production costs and control erosion. But some combinations of conservation tillage and weed control that offer lower production costs and better erosion control have sufficiently lower probabilities of high yield to make them economically unattractive.

A study was conducted at Urbana-Champaign to obtain information about combinations of conservation tillage and weed control for corn and soybean production systems. The study included five tillage systems, ranging from intensive to no-tillage, and preplant-incorporated, preemergence, and postemergence weed control alternatives. The study was begun in 1979, and data from the 1980 to

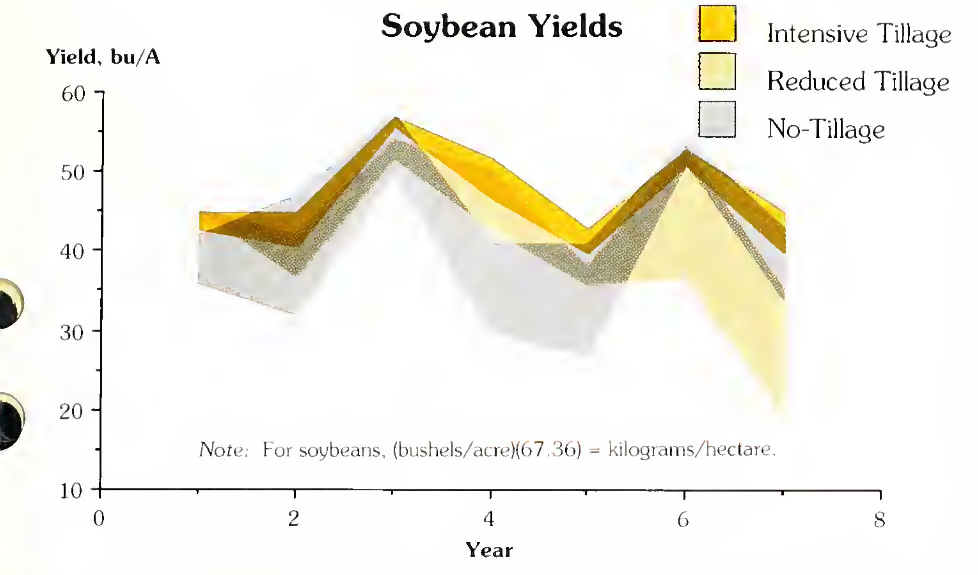


Figure 3. Soybean yield range achieved with each level of tillage includes data from preplant-incorporated, preemergence, and postemergence weed control alternatives. All data are for Corsoy-79 cultivar, seeded in 30-inch rows.

1986 growing seasons have been analyzed. The data from the three intermediate levels of tillage were similar and were grouped together and labeled "reduced tillage."

- *Intensive tillage.* After corn harvest, the land was disked and moldboard plowed in the fall. In the spring, the soil surface was leveled by disking, and then a seedbed was prepared and herbicides incorporated by disking and field cultivating before planting soybeans. The crop was cultivated once. After soybeans were harvested, the tillage treatment was the same as after corn harvest except that a chisel plow was used in place of fall disking and moldboard plowing and that corn was planted in place of soybeans.
- *Reduced tillage.* Of the three reduced-tillage systems, two utilized either a sweep plow or disk for fall tillage following corn harvest. A third system included the use of a subsoiler-bedder to form ridges in the fall, following both corn and soybean harvest. Spring tillage operations were similar to the intensive tillage system.
- *No-tillage.* Corn was planted, without preplant tillage. Soybeans were planted, without preplant tillage, but corn stalks from the previous stand were shredded.
- *Tillage rotation.* In a tillage rotation system, after 3 years in which three crops (corn, soybeans, corn) were planted using no tillage, intensive tillage was used for one crop (soybeans).

Effort was made to perform all operations at a time and in a manner appropriate for that system. All tillage was done when soil moisture conditions were favorable. Planting was accomplished as soon as weather, soil conditions, and scheduling permitted. So that the same herbicides could be used with all tillage systems, herbicides selected were those that could be preplant-incorporated or applied preemergence.

The tillage systems were evaluated on the basis of weed control, stand establishment, surface residue cover, soil-nutrient profile, and yield. Data collected (Figures 2 and 3) illustrate the interaction of tillage system and weed control alternatives. Conclusions about alternatives for tillage system and weed control alternatives follow.

1. *A rotation tillage system* consisting of 3 years of no-tillage followed by one year of intensive tillage can be used successfully on imperfectly to poorly drained soils to produce high yields of both corn and soybeans.
2. *For corn-soybean rotations,* preplant-incorporated chemical weed control options can provide levels of control that preclude yield losses due to weeds. As tillage is decreased, weed pressure increases; and in years with above-normal rainfall early in the growing season, either additional early preplant or postemergence weed control practices, or both, may be necessary, particularly in no-tillage systems.
3. *Corn stand establishment* in corn-soybean rotations by presently available planting equipment is not affected by tillage system.
4. *Following corn,* surface residue cover of at least 20 percent will remain after soybean planting in all except intensive tillage systems. Following soybeans, surface residue cover of at least 20 percent will remain after corn planting only in the no-tillage system, if anhydrous ammonia is knifed into the soil before planting the corn.
5. *Surface applications* of lime, phosphorus, and potassium will increase the pH and the levels of phosphorus and potassium in the surface soil layer (0 to 3 inches) when intensive tillage is not used. Rotation tillage can assist in distributing nutrients in the root zone, while reducing tillage expense.
6. *If managed* to adequately control weeds, conservation tillage systems, on imperfectly to poorly drained soils, can produce corn and soybean yields that are comparable to yields obtained from intensive tillage.

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Soybean Physiology

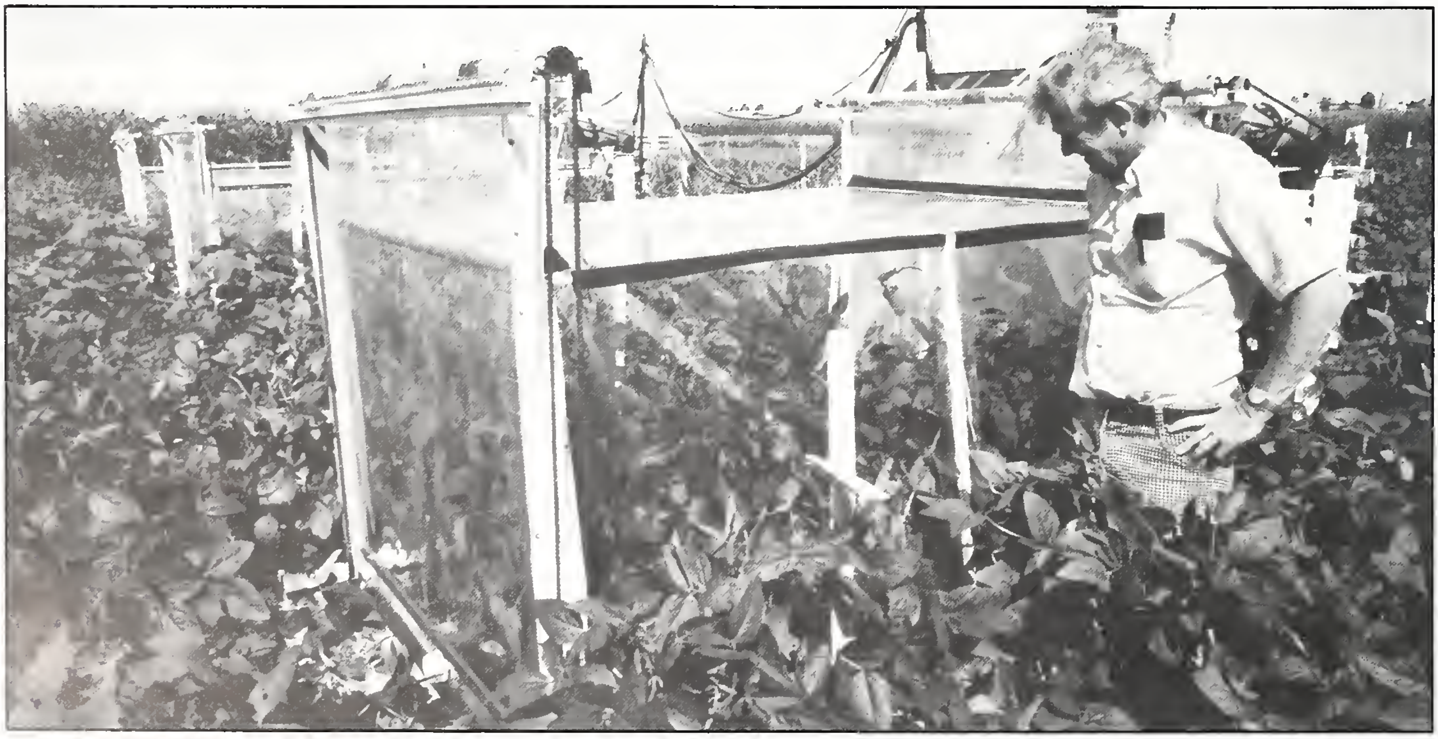
An intricate balance exists among the many physiological and biochemical processes of a soybean plant. These processes are responsible for the plant's orderly transition from seed germination, through vegetative growth, to reproductive growth and the formation of seed. The close interrelationship between the products of photosynthesis and nitrogen metabolism in the vegetative parts of the plant, and the subsequent partitioning of nitrogen and carbon to seed protein and oil have been the subjects of considerable research interest by U.S. Department of Agriculture plant physiologists with the Agricultural Research Service (ARS) at the University of Illinois. Plant physiologists are interested in these physiological processes, for understanding their limitations and interactions will help improve soybean productivity.

Nitrogen. My research has focused on increasing our knowledge of the possible limitations in the pathways of nitrogen metabolism in the soybean. Because the soybean is a legume crop, it can assimilate nitrogen both from the soil, mainly in the form of nitrate, and from the atmosphere through symbiotic N_2 fixation. This type of fixation occurs when bacteria called *Bradyrhizobium japonicum* invade a soybean root and cause the formation of a tumorlike nodule that can convert atmospheric N_2 to ammonium for the plant.

Utilization of soil nitrogen and symbiotically fixed nitrogen are both complementary and competitive. They are complementary in that symbiotic N_2 fixation supplies nitrogen to the plant when soil nitrogen becomes depleted. They are competitive in that the availability of soil nitrogen inhibits not only the infection process but also the functional activity of nodules once they are developed. Fertilizer nitrogen is not generally recommended for soybeans: mineralization from the high organic matter soils of the Midwest Corn Belt area assures that the soybean crop will be exposed to appreciable levels of nitrate, particularly in the spring.

Experimental studies have shown that from 50 to 75 percent of the total nitrogen used by the soybean is derived from the soil. It has been repeatedly shown that the soybean prefers to use nitrate before the rhizobia bacteria successfully infect its roots and initiate symbiotic N_2 fixation. The inhibitory effect of nitrate on successful infection and subsequent nodule development has been the subject of numerous studies, but no definitive proof has yet been established for how inhibition is accomplished.

Recent research has led to the selection of several soybean nodulation mutants that tolerate nitrate more than Williams, the parent line. Some of these mutants will nodulate at nitrate levels that are 15 times higher than the level that completely inhibits nodulation of the parent line. Preliminary results indicate that the level of nodulation is controlled by a single recessive gene. Incorporation of this trait into



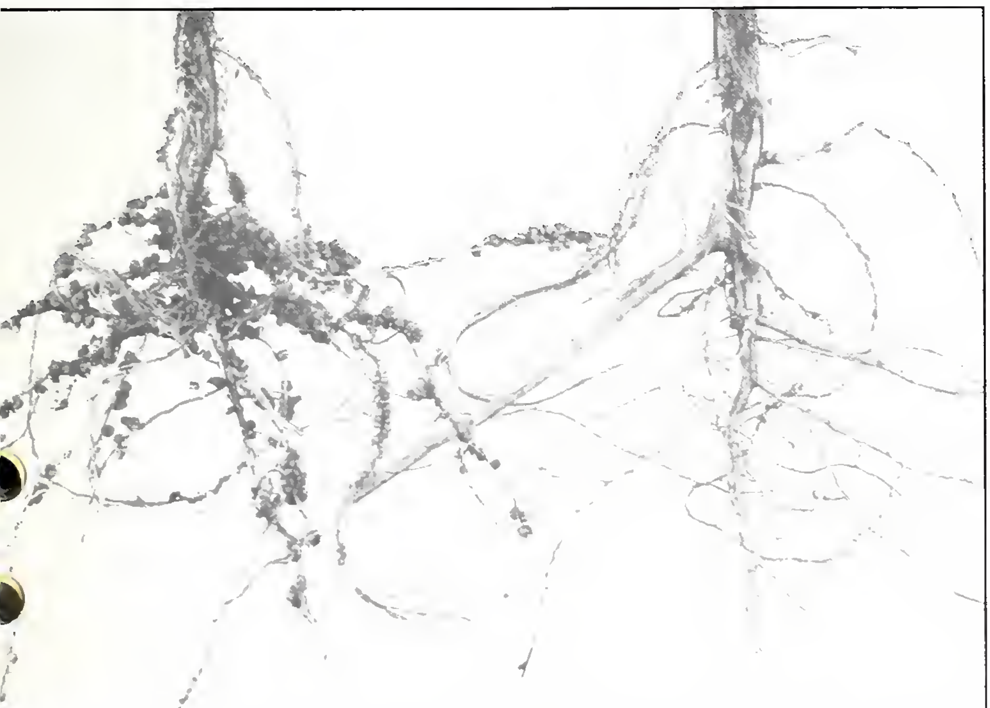
Measurement of canopy photosynthetic rates of soybean cultivars in field plots is one area of study pursued by D.B. Peters, USDA-ARS scientist at the University of Illinois.

other agronomic lines, therefore, will be relatively easy if it is found to be agronomically valuable.

Another line of current research is the selection and evaluation of soybean mutants with altered capability to take up or metabolize nitrate. These mutant types are considered desirable because nitrate uptake and metabolism inhibit nodulation in the soybean. Blocking this uptake or metabolism may partially alleviate the inhibitory effect of nitrate on nodulation. Although mutants have been selected with less capacity to metabolize nitrate, these mutants have not enhanced nodulation because enough of the enzyme that catalyzes the reduction of nitrate remains to metabolize all the incoming nitrate.

Carbon. It now appears that the availability of carbon may limit soybean productivity more than the availability of nitrogen. Carbon is made available to the plant by photosynthesis. During photosynthesis, carbon dioxide diffuses from the air into leaves and is converted into carbon-rich sugars by sunlight energy. These sugars are used for energy and provide skeletons for plant structures. The amount of photosynthesis by soybean canopies, therefore, is a major limitation to the efficiency of production. Research by William L. Ogren and other USDA-ARS scientists at the University of Illinois is attempting to decrease this limitation.

One direction their research has taken is photorespiration, a process that occurs concommitantly with photosynthesis and that wastefully converts sugar back to carbon dioxide. Stopping photorespiration in the laboratory increases photosynthetic productivity by 50 percent, so there is great potential for improvement. Researchers at the University of Illinois have determined that photorespiration is initiated by the same enzyme that begins photosynthesis because atmospheric oxygen replaces carbon dioxide at its active site. They subsequently determined that photorespiration could be decreased if the enzyme were improved so that it reacted more rapidly with carbon dioxide and less rapidly with oxygen. Examination of this enzyme from several plant species showed that variation occurs in nature, but that the soybean enzyme had already evolved to become one of the most efficient. Researchers are now attempting to improve this enzyme and thus the efficiency of photosynthesis by applying new techniques developed by plant biotechnology.



Nodule development on a mutant selection (left) and the parent line, Williams (right), under field conditions. The level of soil nitrate was sufficient to inhibit the development of nodules on the Williams line but not on the mutant.

Headed by Robert W. Rinne, research on improving the quality of oil in soybean seeds has been the focus of yet another USDA-ARS program at the University of Illinois. The seeds of most commercial cultivars contain about 200 grams of oil per kilogram of seed. Of the several fatty acids that are components of soybean oil, linolenic acid is undesirable from a consumer's standpoint. During processing and storage, linolenic acid can react with oxygen in the air or be enzymatically converted to form compounds that give an "off" flavor to edible products made from soybean oil. Currently, most crude soybean oil is treated with hydrogen to lower the concentration of linolenic acid and to improve consumer acceptance and shelf life of the oil.

Hydrogenation, however, is expensive and limits the potential world market for soybean oil because some countries do not use hydrogenated oil. For these reasons, several plant breeding programs and plant physiology programs have endeavored to decrease the linolenic acid in soybean seeds. These programs have produced several lines of soybean germplasm with half the linolenic acid found in most commercial cultivars. Investigations can now focus on the biochemical and genetic basis for low linolenic acid and on the development of agronomically superior lines containing low amounts of this acid.

Soybean physiology, as a discipline, is still relatively young. In the past, it has focused on understanding certain biochemical pathways within the plant. With our current knowledge of physiology and new approaches to biotechnology, however, soybean physiologists in conjunction with other scientists are in a key position to influence positively the soybean's future development by manipulating its physiological processes.

James E. Harper, USDA plant physiologist with the Agricultural Research Service and professor of agronomy □

Associations and Organizations of the Soybean Industry

The Illinois Soybean Program Operating Board (ISPOB) and the Land of Lincoln Soybean Association are two statewide soybean industry organizations that are dedicated to improving the economic welfare of Illinois soybean farmers.

These organizations have a significant responsibility: Illinois soybean production is big business. Since 1977, Illinois farmers have harvested over 9 million acres of soybeans annually. That's more than the combined acreage of rice, peanuts, sunflower, sugar beets, flaxseed, rye, and tobacco that was harvested in the United States in 1986. And Illinois farmers had more acres of soybeans than all the U.S. cotton acreage in 1986.

ISPOB. The Illinois Soybean Program Operating Board was established in 1974, following approval by a statewide referendum of farmers, and is responsible for collecting and administering all Illinois checkoff contributions. The checkoff rate is one-half cent per bushel and is collected at the first point of sale. The half-penny represents an investment of only one mill or one-tenth cent per bushel for market promotion, research, and education. In 1985, the average Illinois farm had 195 acres of soybeans, yielding 38 bushels per acre. Thus, total checkoff for the average farm was \$37.05 in 1985. That's an investment of only 19 cents per acre to improve profits.

Illinois counties are grouped into 18 districts for Board representation, with representatives serving staggered three-year terms. The 18 farmers who are members of the Board administer the checkoff funds collected and make all decisions on the funding of overseas market development activities, research projects, and special educational programs. Board members receive no salary or per diem expenses for their work. The ISPOB operates independently from the American Soybean Association and other state checkoff programs.

Market development. To promote overseas demand for soybeans and products — oil and meal — the Illinois checkoff program sends approximately two-thirds of its funds to the American Soybean Development Foundation (ASDF). The remainder of the money is used in Illinois to fund educational projects, operating expenses, and soybean research projects at state universities. Operating expenses averaged only 9 percent of income for the past 12 years.

ASDF operates independently of other soybean organizations. It receives grants from the Illinois Checkoff Board and other state checkoff boards. The soybean farmers on the ASDF board decide which market development activities should be funded in what countries. Checkoff dollars for market development are matched three-to-one by other parties interested in increasing soybean exports. Approximately six million checkoff dollars (for a total of about \$24 million overall) are spent annually on about 400 projects in 84 countries for market development activities. No checkoff money is ever spent on lobbying or farm policy matters.

ISPOB research funds. In-state research funding from ISPOB for the fiscal years 1974 through 1986 totals \$4.4 million. Since ISPOB was established in 1974, the Illinois Agricultural Experiment Station has received \$2,866,330 for research funding, and the University of Illinois has received \$397,083 for educational purposes.

Funds have been invested for research in several departments of the University of Illinois College of Agriculture — including agricultural economics, agricultural engineering, agronomy, animal science, entomology, food science, and plant pathology. Funds support a breeder position in agronomy and an Extension specialist in soybeans. Several different types of funding agreements have been made to support research, including fellowships for graduate students, postdoctoral research funding, equipment purchases, and technician support. When special problems became evident, such as the spread of the cyst nematode in Illinois and the recognition of soybean sudden death syndrome, the ISPOB provided funds for initial research. New research opportunities in soybean utilization, marketing, and production are always candidates for ISPOB funding.

ASA. The Land of Lincoln Soybean Association is the Illinois affiliate of the American Soybean Association (ASA). Twenty-six state associations make up the ASA, which is headquartered in St. Louis. Like ISPOB, the Land of Lincoln and the American Soybean associations are organizations of soybean growers.

The objectives of the Land of Lincoln and the American Soybean associations are "to promote profitable soybean production for U.S. farmers and the total soybean industry; to monitor and influence U.S. governmental programs and policy to represent the best interest of U.S. soybean farmers; to promote utilization of U.S. soybeans and products worldwide through cooperative farmer, industry, and government market development programs; to assure a free world market for soybeans; to assure adequate support for soybean research; to inform U.S. soybean farmers of current production and marketing information."

NSPA-NSCIC. The National Soybean Processors Association (NSPA) established the National Soybean Crop Improvement Council, a standing committee with a managing director, in 1948. NSPA believed that making the crop profitable for producers was the most logical way to increase production; therefore, the pro-

cessors supported an increase in production research with their own funds and also by urging state and national legislation to allocate more soybean research dollars. NSCIC was discontinued in 1984.

Commercial Soybean Breeders. Individual soybean breeders employed by commercial seed companies organized in 1976. Their purpose was to have an organizational structure to facilitate cooperation with public breeders (the USDA and the University) for workshops, germplasm exchange, and other educational purposes.

Other support groups. Many other organizations, in addition to the few specific soybean commodity groups, support the soybean industry.

The Illinois Crop Improvement Association has provided research support for soybeans for many years and has sponsored state yield contests.

National organizations involved with the welfare of the soybean industry include the Soy Protein Council; the American Oil Chemists' Society; the Institute of Food Technologists; the Institute of Shortening and Edible Oils, Inc.; the National Food Processors Association; the American Seed Trade Association; the National Grain Trade Council; the National Institute of Oilseed Products; several feed and grain organizations; and the Soyfoods Association of America. This partial list indicates the major role soybeans have in agribusiness.

Conclusion. The soybean industry is suffering from a worldwide excess of soybeans and products and competing crops in relation to effective demand. Other major crops have the same problem. Greater efficiency of production is essential for this industry to compete effectively. Because research in production efficiency is a first step in regaining our markets, researchers at the University of Illinois have a vital role in strengthening Illinois and U.S. agriculture.

William D. Tiberend, executive director, Land of Lincoln Soybean Association, Bloomington. □

In Progress

Centennial Activities

U.S. agricultural experiment stations and the U.S. Department of Agriculture (USDA) are observing the centennial of the Hatch Act. Passed by Congress in 1887, this act authorized the establishment of agricultural experiment stations associated with land-grant universities and set up a nationwide cooperative research system.

William Henry Hatch, sponsor of this act and over fifty other agriculturally important bills, was a prominent Missouri congressman, agriculturist, and breeder of Jersey cattle, Kentucky Trotting Horses, and Southdown sheep. The act that bears Hatch's name is thought by many to be the most important legislative action ever in terms of its effect on the agriculture and economy of the United States and the agriculture of the world.

The Illinois Agricultural Experiment Station will observe its 100th year with a special campus event on March 21, 1988. On that date in 1888, the University of Illinois trustees formally established the Station. Campus faculty and administrators, agricultural and agribusiness leaders, legislators, and other interested persons are invited to participate in this centennial observance.

Morning activities will begin with tours of the agricultural research facilities and laboratories. The afternoon program in the Illini Union will start with an audio-visual overview of the research at the Illinois Station as well as in the national system of experiment stations. Two lectures will follow: one on investment and returns in agricultural research, by Bobby Eddleman, professor of agricultural economics at Texas A & M University, and one on agricultural biotechnology, by a private-sector research director. At a dinner meeting, J. Patrick Jordan, administrator for the Cooperative States Research Service, USDA, will discuss challenges for future agricultural research. □

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Station Centennial

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The Cover

March 21, 1988, marked the 100th anniversary of the state Agricultural Experiment Station in the College of Agriculture at the University of Illinois. The Station was organized in 1888, one year after the passage of the Hatch Act, which authorized a system of stations in land-grant colleges.

"At a time unlike any in the past, we must envision the future."

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The Illinois Agricultural Experiment Station provides equal opportunities in programs.

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Illinois Research

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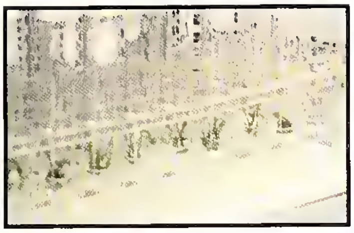

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The Cutting Edge

When I called my mother-in-law to tell her I was resigning as head of the University of Illinois Agronomy Department to become director of the Illinois Agricultural Experiment Station, a long pause followed. Like many people, she was confused by the term "agricultural experiment station." She appropriately assumed that an agricultural experiment station was a place with land, buildings, and other facilities for crop and livestock research. Actually, of course, I would not mind being "banished" to such a station. In fact, the University of Illinois operates several such experiment stations, each of which is part of *the* Agricultural Experiment Station.

The Station itself is a diversified institution that plays many roles in Illinois agriculture. An administrative unit of the College of Agriculture, the Station is responsible for planning, conducting, and administering a broad program of basic and applied research and for training all agricultural graduate students and many undergraduate students in the history, philosophy, and methods of research.

The Station is the primary research and development arm of production agriculture in this state — responsible for generating practical information with which farmers can manage profitable, resource-conserving, environmentally safe farming systems.

Additionally, as few in the general public realize, the Station includes among its activities the research programs in home economics. For example, an entire building houses child development research. In it, scientists are exploring some of the most fascinating and basic phenomena in nature, including how children develop the ability to reason symbolically. Research addressing the most fundamental needs of the human race — the nurture of crops, animals, and families, and the provision of food, clothing, and shelter — is a major responsiblity of the Station.

The Station deals with agriculture in the widest sense of the word. Its clients, originally just the state's farmers, now include the scientists' peers around the world, governments, industries, businesses, foundations, commodity groups, agricultural organizations, environmentalists, conservationists, and, perhaps most importantly, the consumers of agricultural products. Many of these groups provide money that sustains the programs of the Station. That annual support has grown from $15 thousand in 1888 to $25 million in 1986, increasing from $20 to $25 million over the last three years.

In preparing to write this "Directions" for the Station's many audiences, I asked what concerns were present when the Station was created that are still germane and probably will be 100 years hence? During the current financial difficulties in agriculture, I continually emphasize the need for U.S. agriculture to become more competitive and to seek agressively to recapture the large share of world markets for agricultural products it has had in the past — through better programs of production, processing, marketing, and utilization research. I believe that such competition would be good for the people of the

world, because it would stimulate all agriculture to become more efficient and productive, thus increasing the supply and quality and reducing the cost of agricultural products to the consuming public.

Much to my surprise, I found that William Hatch, writing in 1885 in support of the historic legislation that bears his name, expressed the same concern, as follows. "It is becoming apparent...that the United States have not the undisputed monopoly as the producers of cereals. For many years, owing to the newness and richness of our soils, we had a decided advantage over our competitors, much of which was due to advantages in transportation as well as ease and cheapness of production....The same is true of meat and other agricultral products. While this competition is sharp, and becoming more so...it would seem that every encouragement consistent with economy derived from science and experiment should be given in aid of this great industry. The object should be to increase production at a decreased cost and at the same time to preserve the fertility of our soils."

Despite the challenges we face, I am grateful for the circumstances that permit me to speak for the Illinois Station as it passes its 100th year. In my opinion, no legislative act other than the adoption of the U.S. Constitution has had a greater and more positive effect on this nation than the passage of the Hatch Act, which created the State Agricultural Experiment Station System.

The real wisdom of our forefathers was not so much in creating the experiment stations as it was in placing the stations in land-grant universities and in adding the Cooperative Extension Service to that unique institutional structure. Other nations have agriculture colleges, experiment stations, and extension services. Alone, each institution may provide little benefit. Together, they form an enormously effective and productive research and development system. To the extent that this unique instititional structure is nurtured by its many clients and beneficiaries and well managed by its faculty and staff, it will continue to make important contributions.

In reflecting upon those contributions, the authors of the articles in this issue of *Illinois Research* have worked hard to help you know and understand this unique institution and the state agricultural experiment station system of which it is an important part.

To this end, the center section offers a brief history of the Station. Short articles discuss the development of the statewide system of experiment and demonstration fields and the relationship of the Station with the Cooperative Extension Service. And, rather than merely chronicle the history of the various departments within the College, the authors of other major articles have approached their task by looking at the developments within the the five broadly defined subject areas of the College — plant and soil sciences, animal and veterinary sciences, human sciences, social sciences, and engineering sciences.

Donald A. Holt, director, Agricultural Experiment Station

Plant and Soil Sciences

Robert W. Howell and Russell T. Odell

About 80 percent of the USDA's soybean germplasm collection is maintained at the University of Illinois. Shown here are a few of the 8,000 varieties and strains of soybeans, wild soybeans, and other closely related species represented. Every year over 1,000 of these exotic varieties are grown by the University.

Plant and soil sciences have been a part of the agriculture program since the earliest days of the University of Illinois. Research has focused on the characteristics and fertility of the soil and on the important crops of Illinois — corn, soybeans, small grains, forages, fruits, ornamentals, vegetables, and trees — and on the weeds, diseases, pests, and environmental hazards that confront them.

Although there was no professor of agriculture in the early days, Thomas J. Burrill, who joined the faculty in 1868 as instructor in algebra, was interested in fire blight of pears. His report in 1878 to the Board of Trustees was probably the first report that bacteria cause disease in plants. Burrill was called the "Father of the College of Agriculture."

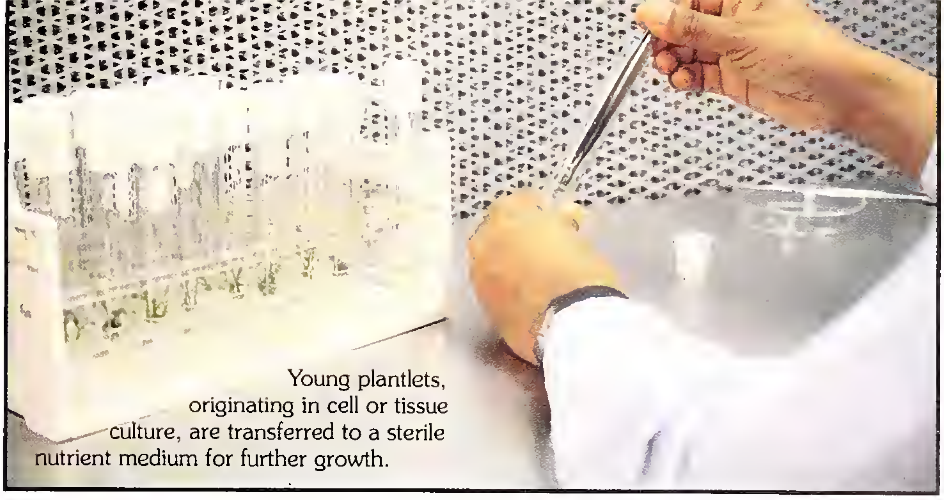
Manly Miles, a physician who had left medicine to join the faculty of Michigan Agricultural College, served as a nonresident professor of agriculture at the University of Illinois in the early 1870s. In 1875, he was appointed professor of agriculture. During his one-year stay, he established a series of plots to study the effects of different cropping systems on yields. These plots were later named the "Morrow Plots" in honor of George E. Morrow, a lawyer by training and a well-known writer and speaker on agricultural subjects who was employed as a professor of agriculture after Miles left. Morrow was the first to hold the title of Dean of Agriculture. In 1879, he expanded Miles's cropping system experiment. In 1904, 1955, and 1967, different soil treatments were added to study the interactions between cropping systems and soil treatments. The Morrow Plots, a National Historical Landmark, continue in operation just north of Mumford Hall.

Tree adaptation and woodland management. Initiated soon after the University was established, forest research was quite limited for 70 years. In 1869, the General Assembly appropriated $1,000 for trees and seeds. In 1871, the first forest trees were planted on a 13-acre tract, later known as the "Forestry," northwest of the intersection of Pennsylvania and Lincoln avenues in Urbana. Twenty-four tree species were planted on land that was originally under prairie grass but had been cultivated about 30 years. The growth and adaptability of tree species in this plantation were reported by Burrill and George W. McCluer in 1893 in Illinois Agricultural Experiment Station (AES) Bulletin 26. Subsequent forest growth was reported in the fall 1962 and winter 1983 issues of *Illinois Research*. In 1951, the last remnant of this forest plantation was named "Illini Grove" and designated for recreational use.

The first Extension forester, Clarence J. Telford, was appointed in 1922, and a year later the General Assembly authorized a Forestry Division in the Station. Fifteen years elapsed, however, before funds were appropriated for the Department of Forestry.

Tree species adaptation and woodland management have been important areas of research at field locations throughout Illinois. Over 700 windbreak demonstrations have been developed by Extension foresters in cooperation with farmers on private land.

Emphasis has also been given to methods of treating wood fence posts and crossties with preservative chemicals. Tests were conducted in cooperation with the College of Veterinary Medicine and private industry to determine the effects of wood preservatives on farm animals.



Young plantlets, originating in cell or tissue culture, are transferred to a sterile nutrient medium for further growth.

Corn and soybean breeding. In the 1880s, McCluer and Thomas F. Hunt, assistant horticulturist and assistant agriculturist, observed that self-pollinating reduced vigor, probably influencing corn breeders for many years. In 1896, an experiment on selection for oil and protein in Burr White open-pollinated corn was initiated by Cyril G. Hopkins. The 88th cycle was grown in 1987. Protein has increased by selection to 32 percent, and oil to 21 percent. Conversely, selection for low protein and oil has decreased these components to 5 and 0.5 percent, illustrating the extensive variability in corn. Nondestructive analysis for oil content in seeds by nuclear magnetic resonance was pioneered in the Illinois Station.

Breeding of soybean varieties has been a major project since 1920, when Clyde M. Woodworth joined the faculty. His work and the vigorous promotion of this new crop by William L. Burlison and Jay C. Hackleman were factors in the decision in 1936 to locate the U.S. Regional Soybean Laboratory at the University of Illinois. The Soybean Laboratory, a cooperative activity of the U.S. Department of Agriculture (USDA) and experiment stations of soybean-producing states, was the principal instrument of soybean variety development for nearly 40 years. The variety 'Williams', developed by the Illinois AES working with the USDA, dominated soybean acreage in Illinois and several other states for many years. A USDA reorganization in the 1970s eliminated the Soybean Laboratory as an organizational unit and assigned the staff to other units.

The Illinois Station has been identified with some major and unique units of worldwide significance. Containing more than 100,000 entries, the Maize Genetic Stock Center is the world repository of genetic stocks. The USDA Northern Soybean Germplasm Collection is the leading repository for soybean genotypes, mutants, and soybean relatives. The Crop Evolution Laboratory, established in 1967, has been the principal group studying the evolution of crop plants, especially cereals, and concomitant development of cultivated crops and civilization.

The director of the Illinois Station has statutory responsibility as the state seed certification officer. For more than 50 years, the Illinois Crop Improvement Association (ICIA) has performed seed certification under an agreement with the Station. A similar agreement with Illinois Foundation Seeds, Inc. (IFSI), authorizes it to produce and distribute Foundation seed stocks as prescribed by the director or designated representative. In each case, Station personnel serve as advisers to the companies. The association of the Illinois Station with these private organizations is unique as a model of cooperation, which has stimulated research on variety development and seed problems. Some of this research has been funded by the ICIA and IFSI.

Soil testing. In 1937, Roger H. Bray and colleagues established the identification, composition, and structure of Illite — one of the most common potassium-bearing clay minerals. Further research determined the different forms of potassium in soils and led to the development of a quick test for the amount of soil potassium that is readily available to plants. Bray and his associates also developed methods for determining total, organic, and available forms of phosphorus in soils. One of these methods, the Bray P-1 test for adsorbed phosphorus, has gained general acceptance as the guide for the use of phosphate fertilizer on acid and neutral soils in humid areas of the United States and many other countries. A paper on determination of phosphorus published by Bray and L. Touby Kurtz in 1945 was recently designated a "citation classic" by *Current Contents*. Testing for soil acidity and for available phosphorus and potassium became widespread after 1940, when soil-testing laboratories were established throughout Illinois.

Soil surveys. When Hopkins became head of the Department of Agronomy in 1900, he initiated a statewide program that included a comprehensive survey of Illinois soils, chemical analysis of different kinds of soils, and experiment fields strategically located throughout the state.

The soil-survey program, which had fielded mapping teams in many counties throughout the state, was altered after 1943, when cooperative soil-survey work was resumed with the USDA/Soil Conservation Service (SCS). After 1966, staff members of the Agronomy Department began devoting more of their effort to pedology research, graduate training, and soil correlation. Gradually, the SCS assumed major responsibility for soil mapping and the publication of soil-survey reports. Classic research has been done on natric soils and soils developed in loess and till, which are the most extensive soil parent materials in Illinois. Studies of soil productivity and the rooting pattern of crops are widely used in appraising and managing soils.

Russell S. Stauffer and associates measured the infiltration capacity of different kinds of soil in the field and the disposition of natural precipitation on eight important soils. They also measured the effects of contour farming on soil loss, runoff, and crop yields for

Offering a potential solution to the problem of insects' building resistance to insecticides, a new insecticide promises to be selective and biodegradable. Constantin A. Rebeiz, professor of plant physiology, explains that beneficial insects are untouched, while harmful ones accumulate biochemicals that block their normal metabolism.

sloping soils in Urbana and Dixon Springs to help develop effective erosion-control practices.

Soil nitrogen. Nitrogen is important for plant growth, but it creates environmental problems when it occurs in excess amounts or at improper places. Early nitrogen work of Ogle H. Sears was on nitrogen-fixing bacteria and their relationship to soybeans, alfalfa, clovers, lespedeza, and other legumes. Current research often centers on the partitioning of nitrogen in the soil, crops, and losses to groundwater through leaching and to the atmosphere through denitrification. The heavy isotope ^{15}N has been used to study denitrification. During the last 30 years, it has been demonstrated that soil organic matter is composed of compounds with chemically acceptable structures having recognizable groupings, bonds, and predictable properties and reactions. This knowledge of soil organic matter helps to understand the fate of residual fertilizer nitrogen and reactions with herbicides. It has also been found that much of the nitrogen in sediments and sedimentary rock occurs as ammonium held within the lattice structure of silicate minerals. Sedimentary rock, not the atmosphere as previously assumed, is the largest reservoir of nitrogen in the universe.

Pioneers in plant morphology and pathology. Orville T. Bonnett's pioneering research on developmental morphology of cereals, reported in a series of papers from 1935 to 1970, still stands as the definitive work in that area. Station and USDA scientists cooperated in the development of oat varieties resistant to barley yellow dwarf virus, effectively eliminating this problem in oats.

Tests for color, firmness, and crack resistance developed by horticulturists were important to commercial vegetable producers. Tomato varieties resistant to fusarium wilt were introduced. The causal organism of red stele rot in strawberries was isolated. Resistant varieties were introduced by Harry W. Anderson, who also wrote the first book on diseases of fruit crops. More than 100 varieties of chrysanthemums were introduced.

Plant pathology has been an active area from the earliest days of the University but was not organized as a department until 1955. Previously plant pathologists were located in other departments. Pathologists and plant breeders have been closely associated in developing resistant crop varieties.

Benjamin Koehler began research on corn diseases in 1924, working on ear and stalk rots, seedling blight, and other diseases. The only pathologist on field crops, Koehler also did work on small grains, alfalfa, and soybeans.

Genetic immunity to apple scab was discovered in ornamental crabapples by Station scientists in 1946. In a cooperative program with Purdue and Rutgers universities, this immunity was transferred into commercial varieties. Several scab-immune varieties have been patented, beginning with 'Prima' in 1970.

The organism responsible for brown stem rot of soybeans was identified by USDA scientists at the Illinois Station. Varieties resistant to phytophthora rot were developed by breeders and pathologists cooperatively. Similar cooperation involving nematologists has helped to control the soybean cyst nematode.

In 1954 the first demonstration that a plant virus can multiply in its insect vector was achieved. The importance of mycorrhiza, fungi closely associated with plant roots, was discovered about the same time.

Phytoalexins, antibiotics produced by plants, were discovered in soybeans in 1963 and in corn in 1968 and shown to be important in disease resistance. Soybean phytoalexins were recently demonstrated to be involved in insect resistance.

Race T of *Helminthosporium maydis* was identified before 1970. This finding led to the abandonment of the T cytoplasm as a source of male sterility in corn when southern corn leaf blight struck in 1970.

Since Stephen A. Forbes moved the predecessor of the Illinois Natural History Survey (NHS) from Normal to Urbana in 1885, there have been close professional relationships between the staff of the Survey and the University of Illinois College of Agriculture. In 1941, the first entomologist to be employed by the Cooperative Extension Service was housed in the Illinois NHS. Later, additional agricultural Extension entomologists were employed under similar arrangements. The College established

an Office of Agricultural Entomology in 1966. Staff members in the economic entomology section of the Illinois NHS were appointed to the College of Agriculture faculty that same year.

Solving insect problems. Work in agricultural entomology has focused on finding practical solutions to numerous insect problems, such as the codling moth, Colorado potato beetle, army worms, grasshoppers, and chinch bugs. Except for limited biological and cultural methods, most insect infestations were controlled by arsenicals, Paris green, and other chemicals during the early years. DDT, aldrin, dieldrin, and other chlorinated hydrocarbons — followed by organophosphate and carbamate insecticides — began to be widely used in the late 1940s. DDT residues in soils, plants, animal tissues, and milk and their effects on nontarget species soon alarmed scientists in the Illinois NHS and other groups. The Illinois NHS was among the earliest to conduct research on the hazards of DDT and the new chemical insecticides. In the 1950s, Illinois entomologists began recommending that chlorinated hydrocarbons not be used on livestock and some feed and food crops. The U.S. Environmental Protection Agency later banned these insecticides.

Since the 1970s, a comprehensive system of integrated pest management has been developed that includes careful monitoring of the density of injurious insects and the judicious use of pesticides when necessary.

Plant physiology programs. The Illinois AES was a leader in the development of strong plant physiology programs in several departments. Research on physiological development of peaches provided the basis for legal standards for maturity of apples and peaches. The control of flowering by length of day was shown in carnations, and work elsewhere on its effects on soybeans became the basis for a system of maturity classification still in use.

Studies of nitrogen metabolism in corn and other crops led to publications that made Richard H. Hageman one of only six plant scientists to be included in a list compiled by *Current Contents* of the 1,000 most frequently cited scientists during the period 1965 to 1978. Other research concentrated on the function of membranes and mitochondria (energy-producing organelles outside the cell nucleus).

The weed science program since the late 1940s has been closely allied with the work in plant physiology. Many projects have stressed the mode of action of growth regulators and escape mechanisms of crop plants. It was shown that the types of weeds in a field change in response to cropping pattern and weed-control practices. A trade-off of weed and crop dry matter tended to reflect the productive capacity of a field. A system of weed control based on photosynthetic reactions may provide a new mechanism of weed control.

The USDA began research on photosynthesis in the Illinois Station in 1965 and, a decade later, designated the University as the location of a major center for its work on photosynthesis. Here the mechanism of photorespiration was described — research that led to the election of William L. Ogren, USDA, to the National Academy of Sciences. The work on photosynthesis extends into many departments and encompasses aspects from the subcellular level to field communities.

Work in biotechnology/genetic engineering began in the Illinois Station at least two decades ago but was greatly stimulated by funding from venture capital and traditional sources beginning about 1980. Major events were the award of a 5-year grant from the Standard Oil Company of Ohio (SOHIO) for a Center of Excellence in Genetic Engineering and significant funding to several staff members from Agrigenetics, Inc.

Environmental concerns have been an important part of our research program for many years. For example, nitrogen losses and soil and water losses from sloping land have been studied for 50 years to develop better soil management practices. During recent years, many exotic materials have been introduced into plant and soil systems to control weeds, insects, and diseases. Although the effects of these materials on target species are usually known, their effects on nontarget species and their rates of degradation in soil are often less well known. From 1968 to 1981, intensive research was conducted concerning the effective use of digested sewage sludge on agricultural land. Since 1977, research has been conducted on methods for reclaiming surface-mined land and constructing a productive soil for crops.

Dramatic changes have occurred in research programs within recent years. Funding from private sources has become more dominant. Enactment of the Plant Variety Protection Act of 1970 increased development of varieties of soybeans and wheat in the private sector. Private funders, including SOHIO, Agrigenetics, and crop check-off boards, became more influential in the direction of research.

Robert W. Howell and Russell T. Odell, professors of agronomy, emeriti

Animal and Veterinary Sciences

Richard M. Forbes and W. Reginald Gomes

The centennial of the Agricultural Experiment Station (AES) has given us incentive to review the history and major research accomplishments in animal agriculture at the University of Illinois over the past 100 years.

In 1870, just 3 years after the University was founded, courses and research on animal breeding, feeding, and management, milk production, and veterinary medicine began, but animal husbandry and dairy husbandry were not recognized as separate fields and given departmental status until 1901 and 1902, respectively. In 1918, the farm management unit of the Department of Animal Husbandry also was given departmental status and, in 1932, expanded to form the Department of Agricultural Economics. The Division of Animal Pathology and Hygiene, established in Animal Husbandry in 1917, became a separate department in 1941 and one of the original units in the new College of Veterinary Medicine in 1945. The Dairy Manufacturing Division of Dairy Husbandry became the nucleus of the new Department of Food Technology in 1947.

The departments of Animal Husbandry and Dairy Husbandry were later renamed the departments of Animal Science and Dairy Science. These two units were merged in 1985 to form the Department of Animal Sciences.

Today, the Department operates nearly 2,500 acres of farms and, with the College of Veterinary Medicine, is responsible for all Illinois AES research on animal production.

Research in livestock management. Early work dealt with problems important for the state: animal power, milk production, and quality of meat production. Because horses were the major source of power on Illinois farms, the Department provided information to make the best use of four-, six-, and eight-horse teams, using horse-pulling contests to demonstrate their effectiveness. Similarly, demonstrations of increased income from increased milk production per cow were conducted. These led to the formation of the Illinois Cow Testing Association, a forerunner to the national Dairy Herd Improvement Association, whose title was coined in Illinois. Early AES work described market classes and grades of cattle to facilitate the economical production of beef of high quality. Subsequently, classes and grades of swine, horses and mules, sheep, and meat were described.

Studies of deaths among young pigs led to improved management methods and to the development of the McLean County System of Swine Sanitation. Experiments in drylot feeding were successful in reducing labor costs and in providing more effective disease control. Confinement raising of swine, which later became the norm of the industry, was made possible by research at the University with pigs kept on slotted floors and maintained by various procedures for limiting feed consumption.

Over the years, the influence of Illinois research on dairy management has been extensive, from the introduction in 1905 of the round barn — some are still standing today — to the Dairy Automation Unit, which is the most highly automated, computer-oriented dairy farm in the nation. Also developed at Illinois were computer-driven electronic feeders and in-line automated detectors for mastitis.

Nutrition and feeding. Early research reports on the marketing of grain and forage through livestock and animal products emphasized improving carcass quality and the rate of meat and milk production to maximize rates of return to farmers. The concept of fat-corrected milk (FCM) was developed to recognize that fat content is the major variable influencing the energy value of milk. The use of FCM in research studies was soon adopted in this country and abroad. In early studies on FCM, the bomb calorimeter was used for the first time to determine milk energy content, and quantitative studies were made on the composition of the nonfat milk components.

Early feeding studies involved tests of feeds and mixtures of feeds and determined the economic value of carrying market animals to different degrees of finish.

Understanding the results of these feeding trials required more knowledge of the chemical nature of the feeds and of the amounts required by livestock. The lengthy series of studies on protein requirements of cattle, sheep, swine, and poultry conducted on this campus have made it now possible to devise rations of optimum nutritional quality. Application of these principles has been of immense value, for example, in designing the supplements needed to maximize the efficiency with which swine and poultry can grow and reproduce when fed corn-soy rations. These basic principles of animal nutrition have enabled researchers to understand, detect, and correct nutrient deficiencies.

Two other important contributions to feeding research made by Illinois researchers are the use of antibiotics in farm animal rations to increase the weight gain of growing animals and the implantation of hormones for the same purpose. These techniques have been of great economic value to both the grower and consumer.

Ruminant animals have the peculiar ability to synthesize amino acids in the rumen from either feed protein or from nonprotein forms of dietary nitrogen, such as urea. Cattle and sheep can utilize nitrogen from urea quite efficiently as a major source of amino acids. Researchers at Illinois have shown that high-producing dairy cows cannot use urea as an exclusive source of dietary nitrogen because their need for amino acids is greater than their ability to form them in the rumen.

Rumen microbiology. Cattle and sheep depend on a very complex mixture of microbes in the rumen to digest their

feed. Faculty members conducting research on the metabolism of those microbes have pioneered techniques to measure the utilization and production of nutrients by bacteria in isolation, in the rumen, and in the whole animal. They have devised continuous culture systems to study rumen microbiota and their response to different feed ingredients, nutrients, and toxins. Early studies focused on protein synthesis from urea. Later studies emphasizing fermentation of dietary fiber have shown that treating wheat straw and other substances with an alkaline solution of hydrogen peroxide is an excellent way to stimulate fiber utilization and has great potential economic value. This treatment increases manyfold the cellulose-fermenting bacteria in the rumen of sheep and nearly doubles the digestibility of nutrients.

New species of bacteria have been isolated that attack specific rumen constituents, such as fatty acids or benzoate and phenol derivatives. Other species produce acetate and butyrate from methane, hydrogen-carbon dioxide, carbon monoxide, or other simple compounds.

Nutritional biochemistry. Basic studies in the chemistry of nutrients included research on the products of metabolism of vitamins and the effects of vitamin and mineral deficiencies on the pathways of fat, protein, and carbohydrate metabolism. Characterization of pathways and sites of lipid metabolism peculiar to the lactating ruminant has been an important contribution.

For instance, by using tissue culture of secretory mammary tissue, researchers have found that fatty acids in milk are derived from acetate, not glucose, as is the case in many other tissues. In mammary tissue, most of the glucose is used for synthesizing lactose. Compartmentation within cells of metabolic pathways is very important for understanding and interpreting metabolic aberrations.

Another important problem related to ruminants is that some legume hays induce excessive salivation when eaten. The problem was biochemically solved by the discovery of an alkaloid produced by a mold growing on the hay.

Animal breeding and genetics. In the early years of animal research at the Illinois AES, great emphasis was placed on animal evaluation and judging. Although subjective analyses of animal form is still practiced, research workers have consistently sought objective measures of animal performance for selecting superior seedstock. The first demonstration of the equal importance of sires, compared with dams, resulted in the 1924 equal parent index, which subsequently became the basis for sire selection everywhere.

Illinois scientists were at the forefront of studies on the heterosis (hybrid vigor) gained by crossbreeding cattle and on the inheritance of milk yield, milk composition, and other traits. More recent studies have been initiated to investigate the genetic control of hormone levels in animals, the relationship of those levels to animal production, and the effects of genetic selection on the response of animals to exogenous hormones.

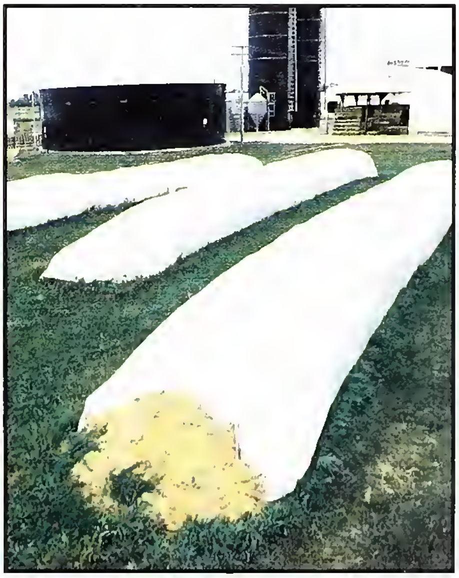
A newly initiated program to incorporate the genes from some Chinese breeds of pigs into domestic animals was undertaken largely because these Chinese breeds have much larger litters than do American animals.

For many years, Illinois scientists have studied blood group antigens and their relationship to economically important traits. By evaluating genetic patterns of these groups, accurate predictions can be made of the susceptibility of animals to porcine stress syndrome, bovine leucosis, and other conditions. With the advent of improved computer technology to study the large amount of information involved, blood typing may be a useful tool in early selection of breeding stock.

Animal physiology. World leaders in reproductive, lactation, and environmental physiology have worked at the University of Illinois for many years.

Reproductive physiology. Classic work by AES animal scientists has been conducted on the morphology, physiology, and biochemistry of spermatozoa, on the preservation of sperm, and on artificial insemination of cattle. Recent work involves the mechanisms of fertilization and the culture, manipulation, and transfer of embryos. In the endocrinology of reproductive processes in birds and mammals, Illinois researchers have been instrumental in understanding the control of ovulation, corpus luteum formation, and the onset and termination of pregnancy; the control of the laying processes in chickens and the factors influencing molt; and processes for the improvement of reproduction in farm animals.

Lactation physiology. In addition to pioneering studies in 1915 on the synthesis and ejection of milk, Illinois scientists have made other important contributions to lactation physiology. They have helped demonstrate the pathways for the biosynthesis and secretion of milk constituents, shown the contributions of these pathways to milk components, and reported that most milk proteins are synthesized within the gland, but that colostral proteins are largely transported from the blood to milk. They have also investigated the pathways of immunoglobulin transport



These dairy cows are fed individually to assess the nutrient value of feedstuffs. Michael F. Hutjens, professor of animal science, monitors their performance. Elsewhere, researchers evaluate forage additives in large silage bags under field conditions.

and the qualitative and quantitative changes in protein secretion during the onset of the dry period.

Environmental physiology. The relationships between animals and their environment, so important to animal health and welfare and to livestock production, have been extensively studied in Illinois. Along with the influence of management practices that might stress animal performance, the effects on animals of temperature, photoperiod, and air quality (airborne dust, ammonia, and bacteria) have been analyzed. High temperatures have been shown to influence the number and vitality of lambs, pregnancy rates in cattle, and eggshell thickness and broiler weight gain in chickens. Novel approaches to minimizing the deleterious effects of heat on animal performance have included adding carbon dioxide to the drinking water of sheep and chickens and cooling the roosts where birds sleep.

Animal behavior. Studies on animal behavior have improved our understanding of animals and their ability to adapt to changing environments. Recent studies have investigated visual, auditory, and social influences on the feeding behavior of pigs and the effects of the environment on social dominance in pregnant animals and on social conflict in growing pigs. Research has aided our understanding of mothering behavior in sheep and its influence on cross-fostering. In studies of temperature preferences in growing animals, researchers have found that young pigs can learn to adjust their environmental temperature by operating a switch to activate room heaters.

Horses and companion animals. With the onset of machine power, the role of horses changed dramatically. Horses, dogs, and cats now serve humanity as sources of companionship and pleasure. The need for research on animal health and performance, however, remains.

Recent studies in horse nutrition and physiology have included estimating the energy requirement for lactation and energy cost of exercise. One study has revealed that the accumulation of lactic acid in the blood after exercise lessens as conditioning increases. The speed of galloping in quarter horses has been shown to be altered by changing the velocity of stride, not the length of stride, as in thoroughbreds.

Nutrition of dogs and cats has been a relatively recent subject of research, emphasizing requirements for protein, amino acid, and mineral elements. This work has been valuable in demonstrating interspecies variation as a part of a broad interest in the animal sciences in comparative nutrition.

Checking a chick's progress, Julie C. Anderson, junior in animal science, notes how different rations affect weight gain.

Meat science and muscle biology. The closely related basic studies of muscle biology and applied research in meat science have been enhanced in recent years by the new Meat Science Laboratory on campus, but there is a rich tradition of research on these subjects. For many years the potassium-40, whole-body counter on campus permitted unique studies into the ratios of fat to lean meat in live animals. More recent research has involved studies in muscle biochemistry, and growth models, focusing on endocrine factors and other agents that repartition nutrients from fat tissues to muscle and on the molecular biology of muscle and adipose tissues. Meat science research has involved the preparation of new products and new processing methods.

Veterinary research. Research in veterinary medicine has traditionally focused on diseases of major economic importance to the livestock and poultry industries. Initially, special emphasis was on preventive medicine programs for dairy cattle and swine and on studies of absorption, tissue distribution, and excretion of drugs used in these species. Later studies have emphasized identifying cause of disease, studying pathogenesis, and formulating and evaluating control measures.

The toxicology program and study of reproductive disease have expanded. The first animal toxicology hotline in the country was established at the University of Illinois. This is a call-in facility that can answer questions relative to poisoning or contamination from agricultural chemicals, feed additives, drugs, pesticides, environmental contaminants, and mold toxins.

The growing need for enlarging interdisciplinary studies to include biotechnological exploration with relevance to recognition, diagnosis, prevention, and control of disease has been recognized. In the future, metabolic processes, genetic engineering, immunology, and herd health improvement will also be studied.

Richard M. Forbes, professor of nutritional biochemistry, emeritus, and W. Reginald Gomes, professor and head, Animal Sciences Department

The Human Sciences

Sharon Y. Nickols, Mary Frances Picciano, and Barbara P. Klein

> We discard the old and absurd notion that education is a necessity to man, but only an ornament to woman. If ignorance is a weakness and a disaster in the places of business where the income is won, it is equally so in the places of living where the income is expended.
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> *Household Science in the University of Illinois, University of Illinois Bulletin*, volume 9, number 22 (April 8, 1912), p. 14. Department of Household Science, University of Illinois at Urbana-Champaign.

The ultimate goal of research in home economics is to enhance human development and improve the quality of life of individuals and the family. Problems of inadequate diets, limited incomes, and the desire to create a more pleasing and efficient living environment captured the attention of home economists in the early 1900s and shaped the direction of future home economics research. Home economists worked closely with their colleagues in agriculture to expand the uses of Illinois agricultural products. This article highlights some of the major research projects of home economists in the first half of the century and traces the contributions of their research to the present.

Studies of home accounts. For nearly 50 years, from 1923 to 1970, the Illinois Family Account Project collected and analyzed the household financial accounts of farm, town, and urban families. M. Attie Souder initiated this cooperative effort between researchers and Cooperative Extension Service (CES) personnel in the Department of Home Economics to help families more efficiently use their family income, to clarify the financial relationship between home and farm, and to serve as a basis for standard-of-living studies in Illinois.

Over the years, Ruth C. Freeman, Ruth A. Wardall, Paulena Nickell, Lita J. Bane, Marilyn M. Dunsing, Jean M. Due, and Jeanne L. Hafstrom gave leadership to the project. Nearly 2,500 families submitted over 10,000 records summarized during the project. Six-hundred-eighteen of these families participated at least 5 years.

Findings from the study include the following facts:

- In 1929, the average cost of clothing for the husband in farm families was \$46. For the wife, it was \$68. But with the addition of each child, the wife's clothing expenditures decreased. The average cost of clothing for children under 6 years of age was \$31, whereas for children between 14 and 18, it was \$70.
- During the Great Depression, these families saved less money and spent less for home repairs and furnishings, automobiles, and recreation. Families made their own soap and burned wood and cobs for fuel.
- As the effects of the Depression subsided, families bought paint, varnish, and wallpaper to make home improvements and purchased curtains, linens, and kitchen equipment as well as larger electrical equipment and furniture.
- In 1936, 28 percent of the total money available for use by farm families came from sources other than the farm business.
- Farm families had housing of lower quality, compared to that of town families. Nevertheless, by 1944, 94 percent of all families had electricity, 74 percent had central heating, 73 percent had running water, and 70 percent had all three of these conveniences.
- Percentages of total family living expenditures for specific categories of purchases did not differ greatly in 1958 and 1968, but the higher proportion of income now needed to pay for medical care began to be apparent in 1968.

Concern for economic well-being is a research priority today. Hafstrom and Vicki R. Fitzsimmons are directing a new study of family economic well-being as determined by resource utilization. In this study CES educators are working with families to maximize their economic well-being in a changing economy.

Nutrient requirements during critical periods of human development. Illinois researchers have been in the forefront of studies on human nutritional requirements. Many of these studies have involved human subjects. These were some of the first studies anywhere to do so.

In the early 1920s, home economics researchers determined that vitamin requirements were enhanced during lactation and that diets ordinarily adequate for adults were inadequate during reproduction. Mary F. Picciano continues to define the nutrients required during human development. Results from her current and previous inquiries have contributed to a growing awareness that nutrition influences foundations laid down during perinatal life and early childhood, the effects of which often only manifest themselves in adulthood.

In the late 1920s and early 1930s, nutrition researchers collaborated with researchers in the Department of Physical Education to evaluate the safety and efficacy of weight-reducing diets and controlled exercise programs. Similar collaboration is evident today in Donald K. Layman's work on how exercise influences nutrient utilization and body composition.

Studies in the 1930s and 1940s directed by Julia O. Holmes, Janice M. Smith, and others serve as the basis for recommended dietary intakes of calcium and magnesium for children, adolescents, and adults. The young subjects in these studies were dubbed the "calcium kids."

Other selected notable accomplishments of early nutrition researchers include:

- A demonstration in the early 1930s of the efficacy of plant sources of vitamin A.
- The discovery that lactose enhances the absorption of calcium and magnesium in children and college women.
- Determination in the late 1930s of child and adult requirements for calcium, iron, magnesium, phosphorus, and protein.

• Establishment of the relative bio-potency of selected foods in meeting protein and mineral requirements.
• The finding in the mid1940s that food grade cocoa does not interfere with human utilization of calcium from milk, in contrast to results from animal studies.

Expanding consumer use of Illinois-grown products. In the early 1930s, Sybil Woodruff tested numerous soft-wheat flours and ingredient proportions to increase the use of Illinois soft-wheat flour in home-baked bread and cakes. By the late 1930s, she had shown the adaptability of Illinois-grown soft-wheat flours for household baking.

Studies of soybeans and soy products from 1930 to 1939, directed by Woodruff, produced significant publications on the use of soybeans as human food. In collaboration with the Department of Agronomy, 95 varieties of soybeans were grown and evaluated for their chemical composition, nutritional value, palatability, and storage quality. Comparisons of methods for freezing, canning, and preparing green and dry soybeans, as well as soy flour, soy sprouts, soy milk, and soy curd were continued in the 1940s by Jean I. Simpson; in the 1950s and 1960s by Frances O. Van Duyne; and in the 1970s and 1980s by Barbara P. Klein. Publications with tested recipes based on the research have been available to the public since 1943. Highlights include:
• From 1930 to the present, published studies of soybean composition and functionality have shown the utility of soy products as food ingredients and nutritional supplements in human foods.
• In 1938, Bulletin 443 *A Study of Soybean Varieties with Reference to Their Use as Human Food* listed seventeen soybean varieties, which had the greatest promise for edible use, based on their appearance, flavor, texture, and handling qualities.
• In 1950, circulars 662 and 664 with numerous tested recipes for fresh green and dry soybeans, soy meal, and grits were published. More than 13,000 copies of another publication, Circular 1092 *Cooking With Soybeans* (1974; revised 1986), have been distributed worldwide.

Symbolic capacity pinpointed: Sometime between the ages of 2-1/2 and 3 years, children grasp the idea that an object can be understood both as "a thing itself and as a symbol of something else." Judy S. DeLoache, associate professor, child development, watches to see if her young subject can generalize from a toy hidden in the model room to find its full-size counterpart.

Work on the home preservation of fruits and vegetables by canning and freezing was begun in 1938. Researchers tested 121 varieties of 21 vegetables and 58 varieties of 18 fruits, most grown by the Department of Horticulture. In a series of studies by Van Duyne and her colleagues, the effects of variety, maturity, canning and freezing treatment, storage conditions, and cooking method on vitamin content and palatability were determined. These investigations are cited frequently as evidence of the need for careful handling of produce to preserve nutritional and eating quality. Results of these and other studies provided the basis for circulars 602 and 835 on home food preservation. The circulars are periodically updated as new information becomes available from current studies by Klein and Mary A. Keith.

The results of this and other home economics research at the Illinois Station have enhanced human resources and improved the quality of family life. Most findings have become so thoroughly absorbed into daily life that they are now taken for granted. For example, hardly anyone anymore discusses the fatigue of homemakers caused by poorly designed kitchen and laundry work areas because research in the 1940s analyzed the problems and recommended solutions that have been largely incorporated into the design of houses. Nutrient deficiencies widespread in the United States 25 to 35 years ago have been virtually eliminated because information about nutrition has been incorporated into our food production, technology, and consumer habits.

This tradition of basic research designed to gain insight into fundamental relationships and applied, problem-solving studies continues in the School of Human Resources and Family Studies.

Note: The authors wish to express appreciation to those who have provided useful information for this article: Martha L. Dunlap, Marilyn M. Dunsing, Annette Y. Feldman, Glenna H. Lamkin, Millicent V. Martin, K. Virginia Seidel, and Clareta Walker.

Sharon Y. Nickols, director, School of Human Resources and Family Studies, and assistant director, Agricultural Experiment Station; Mary Frances Picciano, professor of nutrition; and Barbara P. Klein, professor and chair, Division of Foods and Nutrition

March 21, 1988, marks the 100th anniversary of the state Agricultural Experiment Station (AES) in the College of Agriculture at the University of Illinois. On this day in 1888, the Station was organized, following by one year the passage of the Hatch Act, legislation that authorized a system of agricultural experiment stations in land-grant colleges.

The Illinois Agricultural Experiment Station: A Centennial Perspective

Harvey J. Schweitzer and Benjamin A. Jones, Jr.

History, someone once said, is neither more nor less than biography on a large scale. This is especially true as one traces the development of the Illinois AES and agricultural research at the University: Advances and discoveries are linked to individual administrators and scientists. And, yet, development takes place within changing social, economic, and political scenes — each with its own unique problems, needs, and opportunities.

This article is not intended to provide detailed information about individuals or their accomplishments. Rather, it is an attempt to capture the broad sweep of developments that led from the search for very practical information on farming about the turn of the century to the highly sophisticated research now required. Even as we write, we are humbly aware that today's cutting-edge research will some day be viewed as primitive and archaic.

Historical context. The origin of the network of state stations engaged in agricultural research can be understood and appreciated only in context: The year 1862 was marked by several events of major significance to agriculture in Illinois and the entire United States. The Homestead Act, signed into law by President Lincoln, opened the way for many families to settle on 160-acre tracts in the great agricultural Midwest. Also, the U.S. Department of Agriculture (USDA) was created that year and began gathering statistics, collecting new and valuable seeds and plants, and propagating and distributing those of value.

In terms of its impact on agricultural education, the Morrill Act of 1862 was undoubtedly the most significant piece of legislation ever passed. The act provided that a state might receive 30,000 acres of the public lands within its borders for each senator or representative it had in Congress. Proceeds from the sale of these lands were to be invested and the income used to create and maintain colleges, the primary objective of which was to teach "branches of learning as related to agriculture and the mechanic arts." Citizens of Illinois, led by Jonathan B. Turner of Jacksonville, had been prominent in calling for this kind of education and in drawing up the bill introduced in Congress by Representative Justin S. Morrill of Vermont.

A 1962 USDA publication states that "the first campaign to awaken an awareness that each agricultural college needed an experiment station took form, soon after the ending of the Civil War, at the newly founded Illinois Industrial University," later to become the University of Illinois at Urbana-Champaign. A proposal to establish agricultural experiment stations at land-grant universities was made by Willard C. Flagg, corresponding secretary of the new Illinois Industrial University at a 1871 convention of land-grant colleges.

Prior to the Hatch Act of 1887, agricultural research and experimentation proceeded under research-minded faculty at several land-grant colleges. Agricultural experiment stations had their beginnings in Europe, and students returning from studies in Germany and Scotland took up the cause to get stations established here.

The charter of Illinois Industrial University required that the corresponding secretary of the Board administer a statewide program of farmer-conducted tests of specified field crops. In 1871 the Illinois General Assembly appropriated the funds to purchase, for agricultural research, a 200-acre farm, the center of which is now the Morrow Plots. Both Connecticut and California began station-based research in 1875.

A national system. Not until 1887, however, was a federally supported system of stations established. The legislative act, commonly called the Hatch Act, that provided for this system was approved March 2, 1887. Under the Hatch Act, experiment stations were to be established at land-grant colleges "to aid in acquiring and diffusing among the people of the United States useful and practical information on subjects connected with agriculture, and to promote scientific investigation and experiment respecting the principles and applications of agricultural sciences."

Soon after the passage of the Hatch Act, the Illinois General Assembly gave the necessary "legislative assent," authorizing and directing the University

trustees "to organize and conduct an agricultural experiment station in connection with the Agricultural College of said University of Illinois, in accordance with the terms and conditions expressed in the Act of Congress aforesaid." Two principles guided organization of the Station. First, under the Hatch Act, the new stations were not to be separate institutions, but integral parts, departments, of the colleges; and second, as a department of the University, the Station was to come under the general management and control that governed the university.

Congress did not appropriate money to implement the Hatch Act until February 1888. On March 21, 1888, the trustees adopted a plan of organization establishing "a department of the University of Illinois, which shall be known and designated as the Agricultural Experiment Station." The plan specified that "the experimental work of the Station shall be under the immediate charge of a Board of Direction, consisting of nine persons, one of whom shall be designated as President, when appointed; and all members of said Board shall be appointed by the Board of Trustees of the University, at its annual meeting."

Board of Direction named. Bulletin 1, issued May 1888 by the new Illinois Station, outlines in detail the steps leading to the establishment of the Station, its organization and regulation, the broad areas in which investigations were to proceed, and plans for immediate work.

Under the plan of organization, the following persons were appointed to the Board of Direction: Selim H. Peabody, regent, University of Illinois, who was named president of the Board of Direction; E.E. Chester, vice president, State Board of Agriculture; J.T. Johnson, ex-president, State Horticultural Society; H.B. Gurler, ex-president, State Dairymen's Association; Emory Cobb and Burden Pullen, trustees, University of Illinois; George E. Morrow, professor of agriculture; Thomas J. Burrill, professor of botany and horticulture; William McMurtrie, professor of chemistry; and William L. Pillsbury, who was appointed secretary to handle Station accounts, correspondence, and the publication of reports.

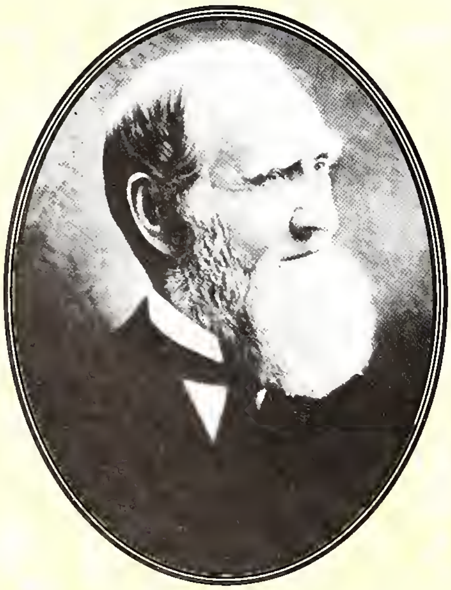
This first Board of Direction selected four areas of investigation for work in 1888:

- The culture of cereal grains and grasses.
- The feeding of animals with reference to growth and meat product.
- The feeding of cattle with reference to the milk product.
- Orcharding and the culture of small fruits and garden products.

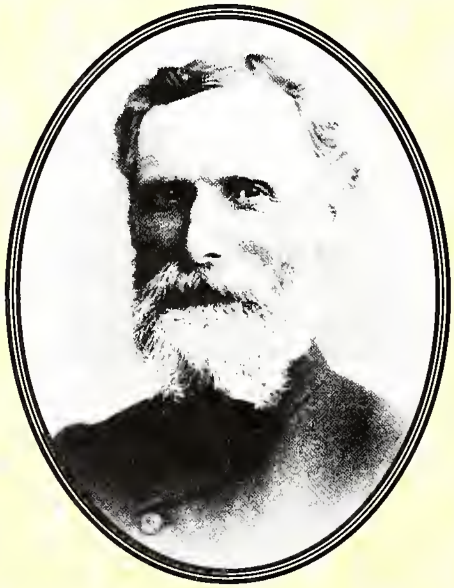
Staffing patterns. Station staff members listed in the first bulletin were as follows: George E. Morrow, agriculturalist; Thomas J. Burrill, horticulturist and botanist; William McMurtrie, chemist; Thomas F. Hunt, assistant agriculturalist; George W. McCluer, assistant horticulturist; and John A. Miller, assistant chemist.

The early work of the Station was under the immediate charge of the Board of Direction. A year after Dean Eugene Davenport arrived on January 1, 1895, University President Andrew S. Draper recommended to the Board of Trustees that a position of director of the Station be created, to be filled by the dean *ex officio*. The Station's Board of Direction would be changed in both name and function to an advisory board that would "recognize the Director ... as the executive officer of all Station affairs."

The Board of Trustees approved this arrangement, which helped to identify



Jonathan B. Turner, who came to Jacksonville in 1833 to teach rhetoric, Greek, and Latin at Illinois College, lead a crusade for higher education of the "industrial classes" and formulated a plan for a national system of universities, which Senator Justin S. Morrill of Vermont brought to fruition with.



The first dean of the College of Agriculture, George E. Morrow was trained as a lawyer and worked for ten years as an agricultural journalist before being appointed professor of practical agriculture at the Iowa Agricultural College, then accepting a professorship at Illinois six months later.

Research by Thomas J. Burrill demonstrated that living organisms cause disease in plants. Burrill held a joint appointment as professor of botany in the College of Natural Science and professor of horticulture in the College of Agriculture. For a time, too, he served as president of the Station's Board.

the work of the Station more clearly with the College of Agriculture and permitted a closer relationship between experimental work and instruction in agriculture.

Thus it was that Dean Davenport assumed the position of Station director in 1896. This organizational pattern, with the dean also designated as the director, remained essentially unchanged until 1965.

On April 1, 1965, the University Board of Trustees made several changes affecting the AES director. The title "Dean of the College of Agriculture, Director of the Agricultural Experiment Station, and Director of the Cooperative Extension Service" was changed to "Dean of the College of Agriculture." The title "Associate Director of the Agricultural Experiment Station" was changed to "Director of the Agricultural Experiment Station and Associate Dean of the College of Agriculture." A similar change was made in Extension administration.

Funding patterns. When the Station was established, it was housed on the top floor of the chemistry building. About $3,500 of the initial $15,000 Hatch allocation was spent for books and periodicals relating to agriculture, horticulture, botany, and chemistry.

Financing the Station's early operation was a critical factor in the Station, the College, and the University. Until about 1900, both the College and the Station were subsisting entirely on money from the federal government — $45,000 annually, as authorized under the Morrill Act of 1862, the second Morrill Act (1890), and the Hatch Act.

State appropriations added. It was obvious that state support was needed for buildings, equipment, salaries, and programs. Dean Davenport prepared a bill for consideration by the state legislature "to provide for the maintenance of livestock at the College of Agriculture and to extend the work of the Experiment Station." Bill 315, as it was known, was divided into sections representing agricultural interests in the state, and each section was sponsored by one or more farm organizations. The bill was passed, carrying an annual appropriation of $54,000, somewhat reduced from the original request. This bill set a precedent for future appropriations.

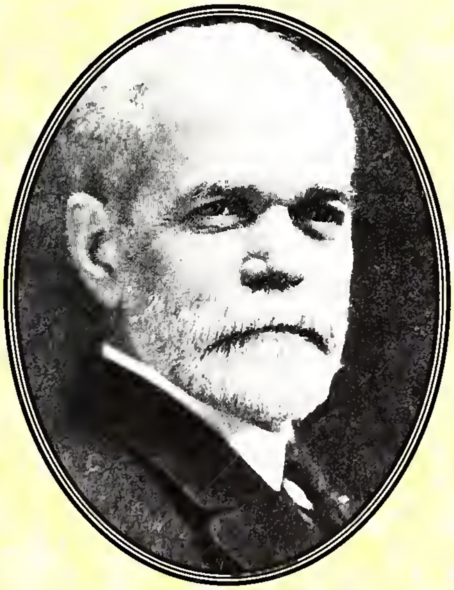
Additional federal funds. The Adams Act of 1906 increased federal funds beyond those provided by the Hatch Act. It also required that the new proceeds be expended only for "original researches."

The Purnell Act of 1925 provided additional annual appropriations amounting to $20,000 for 1926, with stepped increases to $60,000 in 1930 and thereafter for each state station. Not only did the legislation triple the federal funds available to the stations, but it specifically encouraged attention to the economic and social problems in farm life.

The Bankhead-Jones Act of 1935 established formula funding for the stations. Congress enacted legislation giving the public agricultural research system more money — but only if the states provided matching amounts. Distribution to the states was made on the basis of each state's proportion of the country's total rural population.

By the Station's 50th birthday, the expenditures to support the program had reached $613,530. The federal appropriation, by now coming from four different acts, totaled just over $152,000 (24.7 percent). The state appropriation had grown to $386,800 (63 percent), with the balance coming from sales of products left after completing the research and gifts.

In 1987, the Station's expenditures were $28,628,000. Of this, about $4,617,500 was from federal formula



Dean and director from 1896 to 1922, Eugene E. Davenport reorganized the College curriculum to include applied agricultural courses throughout a student's four-year program. When he saw that the initial Hatch funds could not support the entire College, he took his case to Springfield and the people of the state.

Trained in food and sanitary chemistry, Isabel Bevier headed the Department of Household Science from 1900 to 1921. She was determined to build academic respectability into the teaching and research program of home economics while not neglecting entirely the public pressures for a cooking-and-serving school approach.

Before becoming dean and director in 1922, Herbert W. Mumford headed the Department of Animal Husbandry, which he organized into divisions for each class of livestock and for nutrition, genetics, and extension work. Although trained as a livestock specialist, he was particularly interested in economics.

funds, $3,598,300 from other federal agencies (that is, the National Science Foundation), $12,395,300 from state appropriation, $3,133,300 from the sale of products, and $3,507,500 from private gifts.

There has been a dramatic shift in the support of the Station in the past 50 years. While the state provided 63 percent in 1938, today it provides only 44 percent.

Impact on land-grant schools. Passage of the Hatch Act and the subsequent establishment of the network of agricultural experiment stations helped breathe life into the new and struggling land-grant colleges, many of which were experiencing difficult times in building agricultural programs and recruiting faculty and students. In his book *Fields of Rich Toil* (1970), Richard G. Moores refers to the passage of the Hatch Act as a "second birth" for the land-grant colleges.

During its first 2 years of operation, the Illinois AES conducted over 100 experiments in field crops, cattle feeding, dairying, and horticulture. Board President Peabody stated in the first AES bulletin:

> *The officers of the Station desire to be in direct personal communication with the agricultural public, particularly of the State of Illinois. Information which the Station has upon any subject within the scope of its operations will always be given promptly and cheerfully. Questions will be answered directly by correspondence, and, if thought to be of general interest, the answers will be given through the bulletins, or through the press.*

Not only did the federal funds for agricultural work, modest as they were, infuse a new spirit of optimism in the College of Agriculture, but also the practical nature of the investigations increased support among the farmers. By the close of Peabody's administration in 1891, more than a score of bulletins had been published, and experiments were being conducted at Mattoon, Odin, Flora, and Farina.

Credit, too, must be given to experimental work that predates the Illinois Station. As part of its successful bid to have the University located in Urbana, Champaign County had donated three farms to the new institution. These consisted of a 410-acre "stock farm," a 160-acre "experimental farm" adjoining the campus, and the 400-acre Griggs farm. Although the management and operation of these farms were serious problems, experiments were conducted. A most significant development occurred when Morrow, professor of agriculture and the first dean of the College, laid out a series of plots modeled after the Rothamsted plan for agricultural experimentation that he had observed in England. The Morrow Plots, though considerably smaller today, now are the oldest continuous experimental plots in the United States and were declared a National Historic Landmark in 1968.

Morrow was appointed president of the Station's Board of Direction in 1891 following Peabody's resignation as University regent. Morrow in turn was succeeded as president in 1894 by Burrill.

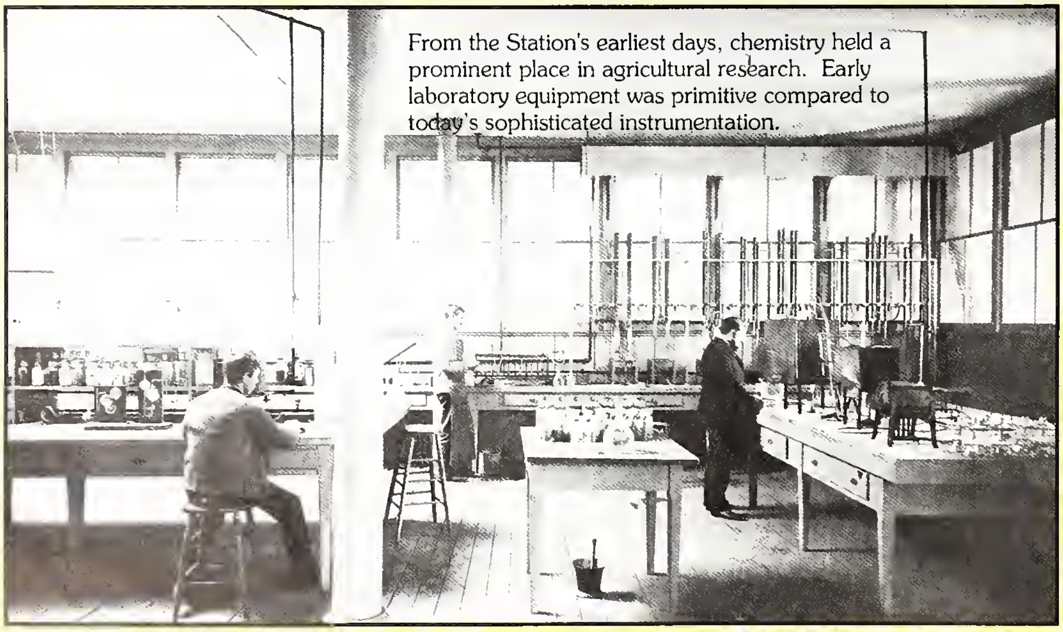
While the Station seemed to be making progress in research and experimentation, the College of Agriculture was experiencing severe problems. Enrollment in agriculture had declined from 49 in the 1870s to an average of 10 students through the 1880s and 1890s. Profits from operating the University farms decreased to an average balance of less than $600 from about 1880 to 1894.

Some of the initial enthusiasm for agricultural education had given away to apathy and even open hostility. It appeared that the only hope for the future of agricultural education lay in the development of an agricultural science geared to the needs of farmers. This was the challenge laid at the doorstep of the College and the Station. Other factors key to the development of the Station, in addition to sound scientific research, were administrative leadership, adequate funding, and broad public support.

A turning point. Davenport was dean of the College and director of the Illinois AES from 1895 to 1922. In 1911, he wrote in a personal letter that "this College is to have a glorious future. A turning point in its history has been established this winter." Moores (1970) notes: "During the remaining eleven years of Davenport's administration, the College of Agriculture of the University of Illinois became one of the leading institutions of its kind in the United States."

Student enrollment in this period increased 75 percent, the staff doubled in size, state biennial appropriations increased, and more than a dozen agricultural buildings were erected. Over 1,200 acres of farmland were added to the University holdings.

During Davenport's tenure, the Smith-Lever Act (1914) established the nationwide Cooperative Extension Service and strengthened the linkage between agricultural research and the educational needs of farm families and communities.



From the Station's earliest days, chemistry held a prominent place in agricultural research. Early laboratory equipment was primitive compared to today's sophisticated instrumentation.

The Old Agriculture Building, later renamed Davenport Hall, was completed in 1900. Photo, c. 1902.

Golden age of agriculture. Agricultural historians refer to the period from 1900 to 1920 as the "golden age" of agriculture — when farmers enjoyed a relatively satisfactory relationship to the rest of the economy. Both the College and the Station made considerable progress during the period. When World War I brought a new set of challenges to agriculture and its institutions, extreme pressure was placed upon farmers to provide not only the food and fiber needed for the war effort but also to supply the needed labor off and on the farm.

The war years were followed by a collapse in farm prices in 1920 and 1921 as supply exceeded demand, land prices rose to a peak, and farmers faced a heavy burden of debt. New technology emerged that would have profound effects on agriculture, notably the development of the gasoline-powered tractor, the grain combine, hybrid seed corn, electricity on the farm, and crossbreeding and artificial breeding in livestock and poultry.

The depression years of the 1930s brought new financial pressures on agriculture as well as other sectors. Establishment of the Farm Credit System in 1933 and a series of legislative acts were attempts at the federal level to deal with the farm crisis.

Major contributions by broad areas of investigation are described by other writers in this issue of *Illinois Research*. And the scientific work and writings of researchers are well documented in the annual reports of the Station until 1948 and thereafter in the biennial reports.

The sweep of events and the challenges for agricultural research are, perhaps, best gleaned from the comments of the Station directors as they prefaced these reports of research accomplishments. Consequently, where space permits, we have tried to let their own words summarize the Station's concerns and achievements at various points in its development.

Objectives at 50. In the *50th Annual Report* of the Station, Dean Mumford elaborated on what he felt were the primary objectives of the Illinois AES. The June 17, 1938, issue of *Science* also reported the objectives in an abstract of an address by Mumford on the 50th anniversary of the Station (March 1938).

Mumford's first objective dealt with the conservation of the land resources of the state. The establishment of the Morrow Plots in 1876 and the initiation of soil surveys in 1902 were referred to as beginnings of "an unbroken program of research" dealing with land resources.

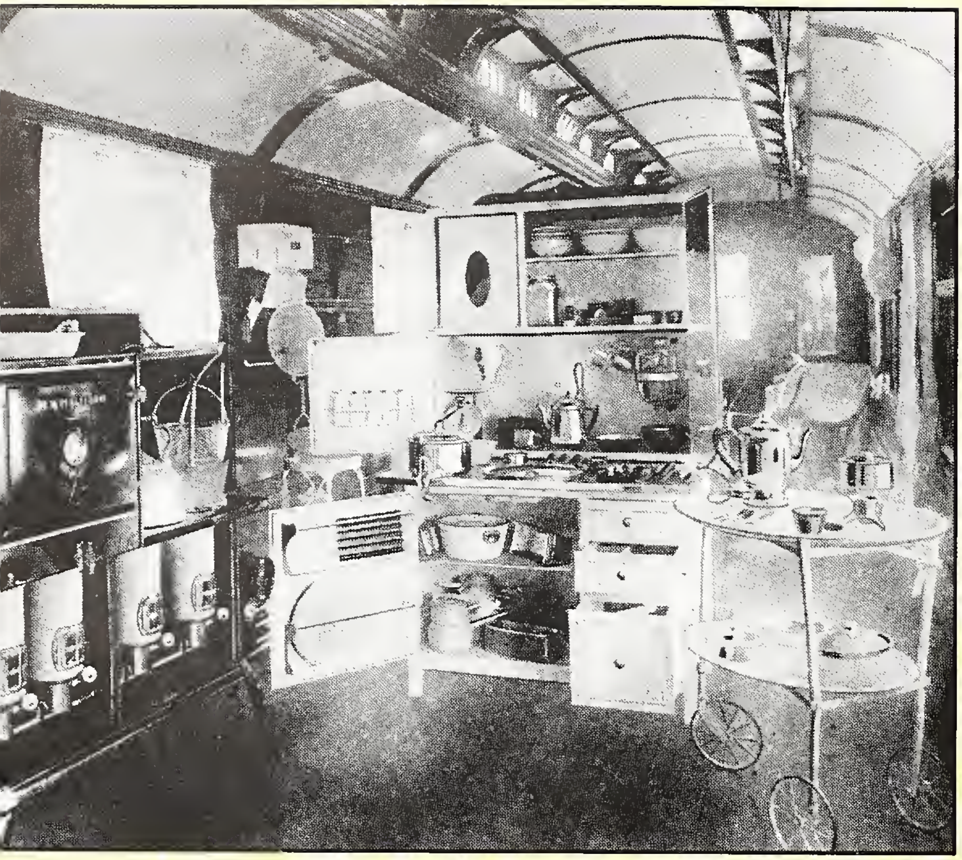
Following this, Mumford listed five other major objectives of the Station:

- To reduce production and marketing costs;
- To improve the quality of farm products;
- To help farmers adjust their production to demand;
- To broaden the market outlet for farm products; and
- To discover facts that will enable homemakers to know better how to feed their families, utilize homegrown food, and better use their incomes.

Dean and Director Mumford died in 1938, after 16 years as the Station director. He was succeeded by Joseph C. Blair, head of the Department of Horticulture. Upon Blair's retirement a year later, Henry P. Rusk served as dean and director from 1939 to 1952. Before being named dean, Rusk had headed the Department of Animal Husbandry.

The war economy. The Second World War impacted the work of the College and the Station in many ways. In October 1948, Rusk submitted a 9-year Station report covering the years 1938 to 1947. He referred to the drastic adjustment in agriculture that took place during the war period: "The events of a single day shook it out of the depressing atmosphere of restricted acreage and troublesome surpluses into the compelling necessity of unlimited production." Adding: "The greatly expanded production of Illinois farms during the war emergency was made possible in no small measure by a huge reservoir of information relating to crop and livestock production that had been built up by the research program of the agricultural experiment stations of Illinois and other midwest states."

An example Rusk gave of agriculture's quick response to need was the Illinois farmers' ability to produce hemp immediately because the soil and cultural requirements of the hemp plant



Innovative methods were used to bring the results of research and development to the public. Traveling throughout Illinois in 1916, this demonstration railcar was used effectively by the home economics staff to bring information on labor-saving devices to thousands of families. Other states had used trains earlier for demonstration work in agriculture. In 1911, 70 trains in 28 states reached an estimated one million families with educational lectures and demonstrations.

had already been determined in our Illinois Station.

During this period, research was also done on problems associated with the military. For example, a project was undertaken in the air-conditioned room in the animal nutrition laboratory to determine what, if any, losses of food nutrients occur through the skin of human subjects under hot, arid conditions characteristic of the desert and hot, humid conditions characteristic of the jungle.

Postwar adjustments. With the war emergency over, the Station research and Extension programs helped agriculture adjust to more normal times. One task was to develop and encourage farming practices that would restore the soils of the state to their former level of productivity after years of heavy use and depletion of their stores of plant food. Another task was to put to other uses the marginal land that had been brought into production during the war. The Station also devised soil tests that were quickly utilized in farmer-owned and -directed soil-testing laboratories throughout the state.

Regional research, conducted cooperatively by two or more experiment stations in the 12 North Central states, is mentioned for the first time in the *61st Annual Report* (1947 to 1948). Regional research was facilitated by a 1946 amendment to the Bankhead-Jones Act that established a "Regional Research Fund." Also, the Research and Marketing Act of 1946 provided funding for research and service work in connection with the marketing, processing, and distribution of agricultural products.

Biennial reports. The first biennial report for the Station was issued for the period July 1, 1948, through June 30, 1950. Reports on progress in research continue to be published every other year.

In the first biennial report, Rusk reflected upon the history of research in the Station over the preceding 50 years, noting the increasing complexity and number of problems facing agriculture and rural families. His preface concludes:

> *Progress in agricultural research during the next 50 years will depend on the ability of research institutions like the Illinois Station to train and hold top-flight research workers and to provide continually improved facilities for these workers. It is an expensive program. But scientific research, which is at the core of the advances in our national economy, has proved to be one of our most profitable investments.*

Rusk retired as dean and director in 1952. He was followed by Robert R. Hudelson, who served from March 1953 until his retirement a year later. For two decades, Hudelson had served in the dean's office — as assistant, associate, and acting dean. Louis B. Howard, who had been head of the newly created Department of Food Technology, was appointed associate director of the Station in 1951 and then dean and director in 1954. He served in these capacities until 1965.

More basic research. In writing the foreword for the 1958-1960 biennial report, Station Associate Director Tom S. Hamilton noted that current research was becoming more basic and less applied:

> *No emphasis is placed on researches designed merely to increase yields of crops or of animal products. The researches are either purely basic in character or are concerned with efficiency of production, economy, higher quality of products, more useful products, and more effective soil and water conservation. While not neglecting the current problems of the farmer, our researches are designed to find more permanent solutions to the changing situations in agriculture.*

Hamilton retired in 1962 after 45 years on the staff of the College of Agriculture. Morell B. Russell then became the associate director of the Station.

The 1962-1964 report refers to a major reorganization of the Dixon Springs Agricultural Center, established in 1938, with staff and funds used in research and extension programs being transferred to the appropriate subject-matter departments of the College. Increased emphasis was given in this biennium to the review, evaluation, and projection of the research program.

Progress was made in developing a uniform system of reporting and budgeting of all research projects, regardless of the funding source.

As previously mentioned, in 1965 the system of administrative titles within the College of Agriculture was revised. Hence, Associate Director Russell became Station director and associate dean. Orville G. Bentley, previously dean of the College of Agriculture and Biological Sciences at South Dakota State University, replaced Howard as dean of the College.

Recent trends. In the 1960s, Director Russell noted the increasingly interdisciplinary character of research within the Station and referred to the rapid changes in the technology, structure, and social environment of agriculture induced by new science-based knowledge.

Several research issues, either research underway or needed, surfaced in Director Russell's comments in the 1966-1968 report, including: environmental quality; social and economic adjustments arising from technological changes; the entire system of grain handling and merchandising; agricultural finance; disposal of solid organic wastes; ecological consequences of the increased use of fertilizers, herbicides, and insecticides; social and economic changes that accompany the development of industrial complexes in rural areas; and research with international components.

In 1969 Russell was succeeded by Glenn W. Salisbury, who shared his appreciation of the value of an interdisciplinary approach to research. Under his leadership, a Council on Environmental Quality, involving nearly 100 scientists, was established. In the 1970-1972 Station report, Salisbury commented on the returns to public investment in agricultural research, citing statistics from studies in the Station. His conclusion was that "initial results ... indicate that the payoffs from agricultural research are consistent and extremely important to the national welfare."

Reporting on a study of research publication productivity by department, Salisbury said that "on the criterion of research papers published during the 1968-1971 period, nine of the ten departments (for which research is administered solely in the ... Station) ranked among the top ten university departments in their field in the United States."

Studies at Illinois in the 1930s and 1940s serve as the basis for recommended dietary levels of calcium and magnesium for children, adolescents, and adults. These young research subjects, the "calcium kids," participated in the study that earned Julia O. Holmes the Borden award for human nutrition research.

Long-range planning. At a spring 1976 meeting of the University Board of Trustees, presentations were made of the station's history and of its plans and needs for the future. Director Salisbury reported that "out of that interchange grew the long-range program for development of facilities for the Station, the College of Agriculture, and the College of Veterinary Medicine ... termed 'Food for Century III.'"

Salisbury retired in 1978, having served as director since 1969. He was succeeded by Raymond G. Cragle, who opened the 1978-1980 Station report by emphasizing the growth of the human population and the need to meet the material and energy demands of this population as factors to consider in research planning. He stated that "renewable sources of chemical feedstocks and energy must be found, and agriculture is one of the most promising sources of these materials." Furthermore,

> *... agricultural researchers must decide how to use resources to support research that will help society plot a satisfactory course. Academic department heads and directors of agricultural experiment stations must provide greater leadership in assembling isolated research findings into packages of information that will be directly useful to the agricultural community.*

Today. The current director, Donald A. Holt, was appointed on October 21, 1983. Prior to that he was the head of the Department of Agronomy.

Holt's opening sentence in the 1982-1984 biennial report is that "biotechnology is an emerging theme in the research program of the Illinois Agricultural Experiment Station." After elaborating on the basics of biotechnology and its challenges, Holt says:

> *While the rapidly growing effort in biotechnology research is stimulating and promising, we must keep in mind that the strength of our institution is its ability to sustain a very broad program of research and to meet the traditional needs of farmers, homemakers, and agribusiness*

people for useful information.... Everyone must come to understand that the development of new technology is a complex process involving basic researchers, applied researchers, systems research and extension education. It is important to maintain a high level of communication and cooperation among the various parts of this technology development system so that the process of development will flow smoothly, efficiently, and rapidly.

In the most recent biennial report (1984-1986), Director Holt speculates briefly on the next major developments in agricultural science. He refers to the appropriation by the federal government to construct a new biotechnology building, the Plant and Animal Sciences Research Center, at the Urbana-Champaign campus and its importance in enhancing the agricultural biotechnology research programs. He suggests that applying artificial intelligence to agricultural problems is a promising new field and that we will hear more about cognitive development as it relates to human development and to the basic structures of knowledge and language as they may be represented in computers.

His closing paragraph in this latest Station report is particularly significant as we complete the first 100 years of work in the Illinois Station and look to the future:

It is essential for the scientists of the Illinois Agricultural Experiment Station to work on the cutting edge of science and technology in many areas, opening new opportunities for Illinois agriculture and related fields. It is particularly important to expose our students to this pioneering activity in meaningful ways. We must always keep in mind, however, that the applied research, that which provides information directly for farmers, agribusiness, and users of agricultural products, is just as important as the more glamorous and basic areas. It is only through this practical research that the public realizes economic and social returns on its investment in research and education.

In retrospect. As one looks back over 100 years of Station history, several observations seem to be in order. They are both sources of pride in the past and challenges for the future.

- The Illinois Station has remained true to the original intent of the Hatch Act of 1887: to aid "in acquiring and diffusing among people ... useful and practical information on subjects connected with agriculture."
- At the same time, the Station accepts the challenges of broadened research as spelled out in subsequent legislation.
- Agricultural and related research in the Station and the College, coupled with Extension's efforts, has attempted to meet the needs of the times — whether in the "golden years" of agriculture, periods of war and postwar adjustments, or depression.
- Administrators and scientists have worked together diligently in promoting the overall welfare and development of the Station and College within the context of the University.
- Research at the Station is at the "cutting edge" of science and technology, without neglecting the practical aspects of farming, family life, and community.

As we look forward to the second century of agricultural research, it is perhaps fitting that we repeat the words of Dean Mumford from the Station's 50th anniversary in 1938:

In conclusion, it may be observed that I have purposely refrained from anticipating the future of the Agricultural Experiment Station. For this omission I make no apology. I am confident that what the Experiment Station should be and what it is to be may safely be left to those whose responsibility it will be to guide its destinies. Of one thing we may be sure: The need for research with the growing complexities of agriculture will increase rather than diminish in the years ahead.

Harvey J. Schweitzer, assistant director, and Benjamin A. Jones, Jr., associate director, Agricultural Experiment Station

Administrative Officers, Agricultural Experiment Station, 1888 to 1988

Selim H. Peabody, president of Board of Direction, 1888-1891
George E. Morrow, president of Board of Direction, 1891-1894
Thomas J. Burrill, president of Board of Direction, 1894-1896
Eugene Davenport, dean and director, 1896-1922
Herbert W. Mumford, dean and director, 1922-1938
Joseph C. Blair, dean and director, 1938-1939
Henry P. Rusk, dean and director, 1939-1952
Robert R. Hudelson, dean and director, 1952-1954
Louis B. Howard, dean and director, 1954-1965
Morell B. Russell, director, 1965-1969
Glenn W. Salisbury, director, 1969-1978
Raymond G. Cragle, director, 1978-1983
Donald A. Holt, director, since 1983

Associate Directors

William E. Carroll, 1946-1951
Louis B. Howard, 1951-1954
Tom S. Hamilton, 1954-1962
Morell B. Russell, 1962-1965
Raymond J. Miller, 1970-1973
Benjamin A. Jones, Jr., since 1973

Celebrating 100 years
Illinois Agricultural Experiment Station

The Social Sciences

Harvey J. Schweitzer and Chester B. Baker

Social scientists are located in several academic units in the College of Agriculture, but the Department of Agricultural Economics is the academic home for most of them. This article mainly features the development of research in this department and its predecessor, the Department of Farm Organization and Management.

Brief mention must be made, however, of social science research carried on by the Office of Agricultural Communications and Extension Education and the School of Human Resources and Family Studies. Researchers in agricultural communications have analyzed media organizations, evaluated college communications programs, and studied new agricultural information technologies. Graduate studies in extension education have focused on adult education and on the organization and programs of the Cooperative Extension Service (CES). Social science research in the School deals with family and consumer economics, human development, and family ecology.

Early in the life of the new Illinois Industrial University, the rural social sciences received the attention of faculty. John M. Gregory, its first regent (1867 to 1880), and several other faculty members in the College of Commerce taught and wrote about economic problems related to Illinois agriculture. When George E. Morrow was appointed professor of agriculture in 1877, three upper-level courses were offered: Rural Economy, the History and Present Condition of Agriculture, and Rural Law.

Early bulletins on economics. The economic aspects of farming and marketing surfaced early in the history of the College of Agriculture and the Illinois Agricultural Experiment Station (AES). The first Station bulletin with a direct economic approach was Bulletin 50, *The Cost of Production of Corn and Oats in Illinois* (1896), by Nathan A. Weston of the Department of Economics. In 1902, Herbert W. Mumford, as head of the Department of Animal Husbandry and later as College dean and AES director, authored Bulletin 78 on *Market Classes and Grades of Cattle with Suggestions for Interpreting Market Quotations*. Four other bulletins by animal scientists from the next few years dealt with market classes and grades for swine, horses and mules, sheep, and meat. Bulletins on dairy, grain, and horticultural products by staff in dairy husbandry, agronomy, and horticulture appeared from about 1908 to 1915. In 1916, investigations on the economic production of cattle and hogs and the cost of horse labor in the production of farm crops were reported.

Departmental status. On September 1, 1917, the Department of Farm Organization and Management was organized with Walter F. Handschin as head and James B. Andrews and Harold C.M. Case as resident staff members. In place at the end of World War I, the new department was influenced by the economic turmoil of agriculture in the 1920s. The departments of Animal Husbandry, Agronomy, Dairy Husbandry, and Horticulture also had faculty members specializing in the economics of production or marketing.

The Purnell Act of 1925 specifically encouraged research on the economic and social problems that are unique to farm life. As dean, Mumford allotted probably a disproportionate amount of the additional Experiment Station funds provided by that Act to support economic studies. Home economics research also benefited. Laurence J. Norton, Roland W. Bartlett, and Charles L. Stewart were brought into the Station with joint appointments in the Department of Economics in the College of Commerce. During his administration, Mumford also added to his staff several other social scientists who later became faculty members in the Department of Agricultural Economics: David E. Lindstrom and Earl H. Regnier, rural sociologists; Harold W. Hannah, agricultural lawyer; and Garret L. Jordan, economist.

In June 1928, the Illinois AES and the CES inaugurated a project on agricultural adjustment, consisting of one-day fall conferences for farm men and women in each farming area and economic outlook meetings the following spring. The conferences stressed economic approaches to the solutions of farmers' problems but included broader analysis of agriculture in Illinois.

Mumford served 2 years as the acting head of the Department of Agricultural Economics after its establishment in 1932. His 21-member initial staff was drawn from several other departments in the University. Social science research, as well as teaching and extension, in this new department felt the impact of the severe Depression of the early 1930s. Student registration was down, and faculty members were called upon to assist in emergency agricultural programs. Case was granted leave to provide leadership for the nation's farm debt adjustment program; Norton went on leave to work in St. Louis for the Farm Credit Administration, establishing production credit services.

The formation of divisions and specialization of staff. In 1934, Case became head of the Department of Agricultural Economics and organized divisions within it. He gave Stewart the responsibility for land economics; Elmer J. Working, the study of agricultural prices and statistics; and Paul E. Johnston, farm management. Norton took charge of agricultural marketing and finance in 1936; Lindstrom transferred from agricultural administration to take charge of work in rural sociology in 1937; and Hannah transferred from the dean's office in 1939 to take charge of the Department's pioneering efforts in agricultural law.

By 1940, most current subdisciplines were established, except agricultural

policy. Although some staff members were involved policy work at agricultural adjustment conferences and during the Depression, not until the mid1940s were policy courses offered at both the undergraduate and graduate levels.

Marketing and farm management. The first economic studies by faculty were done in marketing and in farm management. Both remain significant areas of research today. Research in marketing has aimed to improve decision making by farmers, marketing firms, and public policymakers. Historically, much work in marketing has been done by Norton and Thomas A. Hieronymous in grain; Bartlett in dairy; Robert C. Ashby and Elmer E. Broadbent in livestock; John W. Lloyd and Ross A. Kelly in fruits and vegetables; and Working, Jordan, Vincent I. West, and Lawrence H. Simerl in agricultural prices.

The Research and Marketing Act of 1964 gave impetus to research by providing federal funding for several years for both research and service work on all aspects of marketing, processing, and distribution of agricultural products. Whereas research on some farm commodities has declined, mirroring the decline in the number of these enterprises in the state, grain marketing — particularly the quality aspects of grain in the marketplace — has received increased emphasis. Major contributions have been made to the design of grades and standards that improve marketing efficiency and quality management of farm commodities after harvest.

Studies in farm organization and management were early major initiatives in both the College and the Department. In 1915, organized farm-management Extension work began at the University of Illinois under the supervision of Case. Illinois pioneered in preparing a simple farm record book for farmers. The interest of farmers in farm accounting and leadership by the faculty led to the organization in 1925 of the Farm Bureau Farm Management Service (FBFM), a cooperative venture between farmers and the University of Illinois. Today over 7,000 farmers work with 70 fieldmen in the FBFM, now called the Farm Business Farm Management Service, to keep detailed records of their farming operations. Farmers benefit from the analysis of their own business, and these supervised records — a source of some of the best farm-management information available in any state — are invaluable for further research and education. Over the years, the research agenda in farm management and production economics has shifted toward studies of farm growth and capital accumulation. Risk management has become increasingly important, and the expanding capacity of our computers has provided new tools for analysis.

Agricultural economists worked with the Farm Foundation in 1938 to sponsor the North-Central Land Tenure Committee, a forerunner of several regional research projects. Station Bulletin 502, *Improving Land Tenure in the Midwest*, resulted from this first regional work.

Rural development. From the earliest days of the Department, rural sociologists gathered demographic and other social data to help rural people improve their community institutions and organizations. Lindstrom and others helped rural people in Illinois reorganize their school systems in the mid1940s. By the 1960s, research shifted to methods of strengthening the rural economic base and maintaining a suitable living environment.

The Rural Development Act of 1972 provided modest allocations for both research and extension work in rural development. Rural sociologists and agricultural economists became involved in studies on rural transportation, local government, and leadership development. These special funds were later folded into regular Hatch and Smith-Lever (Extension) appropriations, but research continues on many socioeconomic aspects of farming and rural communities.

Financial management. Problems in financial management have received much attention in the Department of Agricultural Economics. Studies on investment and capital accumulation and credit in the 1950s and 1960s reflected unprecedented economic growth for farm firms in these decades. In the 1970s and early 1980s, the emphasis of research shifted to cash, credit, and debt aspects of risk management. Financial management has been integrated with production, marketing, and household management. Farmers and financial institutions have benefited from research and extension programs in agricultural finance. International and capital markets are becoming increasingly important for agriculture, and the macroeconomic aspects of agriculture are increasingly emphasized.

A Question of Quality

Are U.S. grain exports of poor quality? Quality changes in exported grain was the subject of a recent video documentary produced by the Office of Agricultural Communication and Extension Education (OACEE). Continuing years of work on the subject of grain quality, Lowell Hill, professor in agricultural economics, led a research team of engineers, pathologists, and entomologists in following a shipment of grain from a Louisiana elevator to processing plants in Japan.

Hill and others in the College have used the program extensively to help American producers and grain marketers understand why U.S. grain received by foreign buyers is not the same high-quality product that leaves the farm. The video program is also a forum for ideas on how changes in grain grading and marketing procedures could improve our grain exports by improving the quality of the product.

The economics of natural resources. Another growing area of research is the economics of natural resources. Studies of our valuable land base have been dominant; and land tenure, markets, and taxation have been stressed for many years in the Department. Recent policies on control of soil erosion, water quality, fertilizer use, and other environmental concerns involving agricultural practices and policies are subjects of study and analysis.

Agricultural and food policy. Research on agricultural and food policy has come to rely heavily on the development of models for predicting the effects of policy alternatives on the farm sector. Values, goals, and politics, as well as economic factors, are parts of this analysis. These studies and models are expanding to include international developments and trade. Studies of farmers' views on agricultural and food

Here (left), research team members use probes to sample corn in a hold of the ocean vessel which carried the shipment. Samples were taken from a grid at five different levels in each hold. Sampling at each step in the marketing pipeline helped determine where and at what rate quality deteriorated.

The research team was accompanied by Grear Kimmel and Bill Creswell, OACEE, who produced a 30-minute video program that documents the work of the researchers and the results of their study.

policies have contributed significantly to the development and understanding of current farm legislation. Increasingly emphasized is the public finance sector. Studies on property taxes and the ability of local governments to provide needed services are changing Illinois policies for assessing property.

Agricultural law. Early work in agricultural law focused on teaching and public service. By the 1970s, however, it became apparent that research must become a significant part of the program. Extension work in water and drainage law led to major revisions of the Illinois Drainage Code. Animal and veterinary law and the legal bases for rural universities in developing countries have been researched. Recently land use, environmental issues, protection of farmland, and taxation have been studied in greater depth.

International agriculture. Closely linked to developments in international agriculture, College and Department social scientists have been involved in institutional development and the research topics of graduate studies both here and abroad. Rural sociologists and agricultural economists have studied new technologies in developing countries, providing technical assistance in studies of production systems and of commodity and financial markets.

New tools and techniques. In the past quarter century, departmental social scientists have developed and adapted new and improved research tools and techniques, including econometric and sociometric methods for estimating production and cost and demand relationships; for identifying the incidences and effects of structural changes in the farm and rural nonfarm sector; and for price forecasting. Programming methods were improved to provide better estimates of responses to market and policy changes and changes in commodity and capital markets. New research methodology and greater computer capability help reduce research costs and expand the range of problems that can be investigated.

Social science research in the Department of Agricultural Economics has developed in response to changing times and needs and has always been closely allied with Extension programs. Although the major divisions of work have remained essentially the same, research priorities have changed, specialization among staff has occurred, and new research tools and techniques have been used. Areas of socioeconomic research are highly complementary. For example, research in commercial agriculture contributes to models that improve public as well as private policy decisions. Research on the problems of rural communities and on natural resources improves the environment not only of commercial agriculture, but also of the general public. All of these areas of research affect and are affected by legal as well as social sanctions brought to bear in the public interest. Finally, all are affected by international events and the rapid development and integration of international commodity and financial markets.

Harvey J. Schweitzer, professor of rural sociology and assistant director, Agricultural Experiment Station, and Chester B. Baker, professor of agricultural finance, Agricultural Economics Department

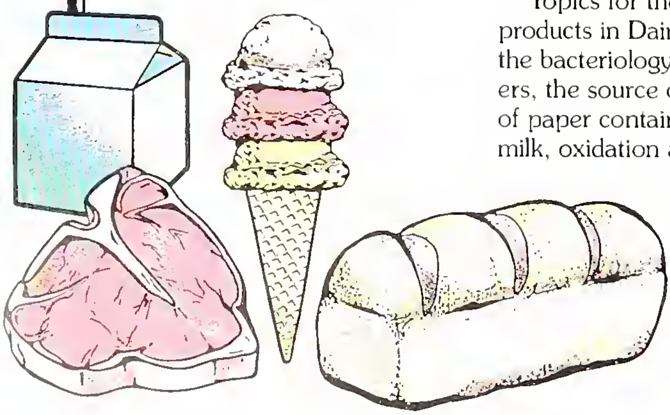
The Engineering Sciences

Benjamin A. Jones, Jr., and Joseph Tobias

When the Illinois Agricultural Experiment Station (AES) was formed in 1888, neither food science nor agricultural engineering was established as a scientific discipline. As agricultural research matured over the next 75 years, however, each developed to meet special needs and became a well-established discipline. They both, nevertheless, have much in common, and currently are collaborating on the development of value-added agricultural products.

Food Sciences

Whether foods are natural or fabricated, their flow from producer to consumer must be safeguarded against deterioration in quality, safety, and nutritional properties. To do so, we must understand the changes that occur during storage and processing. Storage applies both to raw materials, such as corn or animal carcasses, and to the processed products made from them, such as corn syrup and ham. Relatively simple in concept, processing usually becomes complex in execution. As with food production, generally recognized as horticulture and animal husbandry, research on food processing began soon after the opening of the University although food technology was not recognized as a separate agricultural discipline. Even before the Illinois AES was established, two University chemists in 1880 developed a process for extracting sugar from sorghum.



Some of the earliest bulletins of the Illinois Station — 9, 10, 12, 16, 17, and 24 — are research reports on milk. Edward H. Farrington, AES chemist, was responsible for much of this early work although his research was not limited to foods.

Dairy husbandry. In 1902, Wilbur J. Fraser was named the first head of the Dairy Husbandry Department. Fraser is recognized as the founder of the American Dairy Science Association.

In 1947, five faculty members were chosen from Dairy Husbandry to form the nucleus of the new Department of Food Technology, presently the Food Science Department. Although this act conferred an identity on food scientists, research on foods continues in other units and, in some cases, is expanding.

Topics for the early research on dairy products in Dairy Husbandry included: the bacteriology of paper milk containers, the source of bacteria in milk, use of paper containers for homogenized milk, oxidation and other off-flavors in milk, factors that influence the quality of ice cream, whipping cream by aeration, the structure of cheese by X-ray diffraction, and milk composition.

Animal husbandry. Soon after Herbert W. Mumford became the first head of the Animal Husbandry Department, he established a Division of Meats. The first division head was Louis D. Hall (1903), who may have been the first AES worker in the United States to conduct research on meat. Information in his report on market classes and grades of meat (Bulletin 147) was adopted by the government beef-grading service and the meat trade.

Any account of meat science at the University of Illinois without mention of Sleeter Bull would be grossly incomplete. Bull served the Station for 45 years — nearly half of its total existence — and became a legend in his own time. His research encompassed the effect of exercise on meat quality, methods of measuring tenderness and color, studies on the darkening of beef muscle during slaughter, and meat handling problems in locker plants. His contribution and influence go far beyond his numerous research reports. He was a recognized meat expert, an articulate industry spokesman, and effective teacher, textbook writer, coach of the Meats Judging Team, and a man of unforgettable wit and personality.

The emphases of current research in the Meats Division embrace new meat product technology; evaluating new repartitioning agents to produce leaner, more efficient meat animals; and basic studies on meat animal growth, especially muscle and fat tissue.

Household science. Another administrative unit with a heavy commitment to research in food science is the School of Human Resources and Family Studies, established in 1900 as the Department of Household Science. Its first head, Isabel Bevier, was a highly qualified food chemist. Early in her tenure she initiated research on meat cookery and introduced the use of a meat thermometer. In 1908, Nellie E. Goldwaite became the first person in the United States to be appointed to full-time research in a home economics department. She did research on pectin in jelly making and on quality-control factors in bread. Bread making was also of interest to Bevier and Ruth A. Wardall, Bevier's student and successor in 1921 as department head.

Over the years, research programs were developed in several food-oriented areas of Home Economics, as the de-

partment later was called. These included foods, nutrition, nutrition education, and institutional management. Some of the earliest work on the bacteriology of home canning was done here. Sybil Woodruff's research in the 1930s on starch properties has been of enduring significance. In recent years, research on foods has expanded in scope and sophistication. A new Sensory Laboratory provides the focus for possibly the most important properties of foods — flavor, texture, and color — as measured by chemical, physical, and sensory methods. The well-being of the consumer has been addressed in studies of snacking habits, food uses of soybeans, and nutrient retention in foods under home and institutional conditions, as well as by continuously upgraded recommendations for home canning. Studies on the action of water in foods have been initiated, some in cooperation with the Food Science Department.

Faculty members in several administrative units made significant contributions to knowledge of human nutrition. Animal scientists remembered are Harry S. Grindley, who collaborated with Bevier; Tom S. Hamilton; and Harold H. Mitchell, the author of *Comparative Nutrition of Man and Domestic Animals* (1964). William C. Rose of the Chemistry Department has earned worldwide acclaim for his superb work on the biochemistry of essential amino acids. More recent research in the Foods and Nutrition Division of the School of Human Resources and Family Studies is on human milk and infant nutrition, the relation of iron nutriture to immunity, the interaction of exercise and diet in diabetes, the anticarcinogenic components of plants, and the interrelation of exercise and nutrition in muscle development.

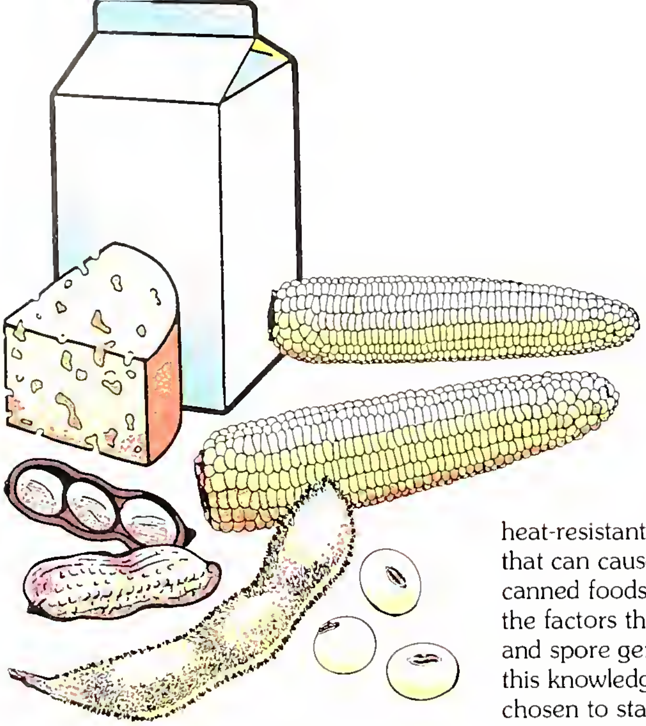
Nutrition research continues to be conducted in Food Science, Animal Sciences, the medical sciences, and several other administrative units. An interdepartmental Division of Nutritional Sciences has been created for teaching graduate nutrition courses and to provide a unified base for nutritionists from diverse disciplines.

For the past 20 years, researchers in the College have had access to a mass spectrometer — the first to be acquired by a college of agriculture. The fall 1968 issue of *Illinois Research* noted the recent installation of the new equipment in the Department of Food Science: "The chemicals responsible for characteristic flavors of foods, the fate of nitrogen in the soil, the nature of substances poisonous to livestock — these are some of the problems that can be studied by use of the mass spectrometer."

Bacteriology. From 1921 to 1948, Fred W. Tanner served as the first head of the Bacteriology Department (formerly a division of the Botany Department; now the Department of Microbiology). He wrote numerous publications on the bacteriology of meat curing, pasteurization, candy, sugar, starch, apple juice, paper food containers, and yeasts; several papers as well as an AES circular (with Grace B. Armstrong of the Home Economics Department) on home canning; and the first exhaustive monograph on food bacteriology.

In 1936, Tanner founded and edited the journal *Food Research*, eventually renamed *Journal of Food Science*, which to this day serves as the principal scientific journal for this field. In 1939, Tanner helped found the Institute of Food Technologists.

Food manufactures. About 1937, Tanner and Paul H. Tracy, of Dairy Husbandry, discussed the creation of a department of food technology. This idea was not new; on March 4, 1895, Dean Davenport stated in a letter to President Andrew S. Draper: "In these days the instruction of specialists only is considered valuable. Live-stock breeding and feeding is itself a broad



subject and as distinct from the agriculture of the field as is Botany from Chemistry...." Accordingly, he proposed that the studies in agriculture be divided into animal husbandry, agriculture proper (soils and crops), and dairy manufactures.

In 1947, "Food Manufactures" (Food Technology) began in the Dairy Manufactures Building in the College of Agriculture with a nucleus of dairy technologists. In a few years, new faculty members were added with interests in the bacteriology, chemistry, and processing of foods other than dairy products.

When the Dairy Manufactures Building became overcrowded, the Quonset hut annex to the Horticulture Field Laboratory was used to house the food-processing section. The Animal Sciences Laboratory and Bevier Hall eventually housed food chemistry and food bacteriology, now known as food microbiology.

Still later, a grant and matching funds made possible the construction of the Burnsides Research Laboratory, named after the principal benefactor, Ethel Burnsides of Paris, Illinois. At the lab, extensive research on dietary factors in atherosclerosis has brought to light many facts about fatty acids, lipoproteins, fats, oils, and cholesterol and the intricate biochemistry that governs their behavior.

From the start, the Department of Food Science had a strong research orientation. About 35 years ago, Z. John Ordal began studying the heat resistance of bacterial endospores, the most heat-resistant forms of microorganisms that can cause spoilage or botulism in canned foods. Much was learned about the factors that influence sporulation and spore germination. By applying this knowledge, conditions can be chosen to start, stop, and restart spore germination at will.

Other significant work included studies on the survival of pathogenic bacteria in freezing, spoilage bacteria of the psychrophilic (cold-loving) type, time and temperature requirements for continuous pasteurization of ice cream, types of films to protect meat quality, and food-poisoning staphylococci. Important research was also conducted on the bacterial injury caused by heat, hydrogen peroxide, freezing, low water activity, and the biochemistry of the "healing" process.

Biotechnology offers opportunities for developing new markets for commodities and agricultural by-products. Microbiologists have developed a continuous system for the fermentation of 2,3-butulene glycol by *Bacillus polymyxa* from whey. Production of butyl alcohol from corn may become an economic reality. Genetic manipulation to incorporate a functional amylase (starch-hydrolyzing enzyme) and the culturing of the fermenting microorganism under butanol "pressure" to maximize butanol tolerance are being studied to solve this problem.

Food chemistry. Pioneering contributions to flavor chemistry were made by Robert M. Whitney. His research, started in the 1940s, provided a sound approach to the chemical characterization of the stale flavor of powdered milk and other off-flavors. He and other faculty members later studied the flavor chemistry of evaporated milk, fresh milk, cheddar cheese, surface-ripened cheese, corn syrup, sodium caseinate, soybeans, and peanuts, and model systems of sugars and amino acids. These studies were aided by the powerful techniques of gas chromatography, mass spectrometry, and nuclear magnetic resonance (NMR).

Knowledge of the chemistry and functionality of proteins is essential in product development and in understanding processing technology. Combined with current research, extensive past studies of milk, vegetable, and animal proteins should yield additional applications and quality, including "value-added" improvements in foods. Most recently, NMR techniques have enhanced our knowledge of the properties of proteins, starch, and bound water.

Fats, oils and other lipids — from either animal or vegetable sources — greatly influence flavor, texture, and consistency, as well as consumer acceptability of foods. These substances may be the origin of both desirable flavors and off-flavors in a great variety of foods. Studies involving the stability of oils in the presence of heat, oxygen, and enzyme attack have improved the quality and extended the storage life.

Significant contributions have been made in the analytical aspects of food chemistry: quantitative tests for the macroconstituents and microconstituents of foods and for drugs, pesticides, and other contaminants; procedures for separating subclasses and components of nutrients; and the identification of isolated components from foods.

Human nutrition. Some findings in food chemistry raise nutritional questions: What are the nutritional properties of heated oils? What are the nutritional properties of proteins from processed foods? To answer these and other questions, nutritional studies in the Food Science Department have been concerned with the effect of processing on nutritional properties; dietary components and cancer; the bioavailability of some nutrients; dietary components and immunity; the behavior and metabolism of some nutrients including vitamins and minerals; and the relation of diet to heart disease. Chemists and technologists in the department have also addressed measures for negating the effect of antinutritional factors, such as the trypsin inhibitor and phytic acid in soybeans, peanuts, and other oilseeds.

In the ongoing effort to apply research expertise to conserving our natural resources, agricultural engineering is among the contributing disciplines. Properly constructed terraces can help solve both erosion and drainage problems.
Photo provided by the Soil Conservation Service.

Food processing. Food technologists at Illinois have led in several developments. Their research on high-temperature processing of milk, cream, and ice cream laid the groundwork for aseptic processing of sterile or ultra-pasteurized fluid milk products and provided basic information on the binding of water and on heat-induced interactions among the constituents of milk. Another pioneering effort was the development and testing of a concept for thermally processed foods in plastic film packages. This work preceded commercial introduction of the process by some 15 years.

Studies of the technology for manufacturing or preserving a number of commodities were major efforts that helped some investigators become known as specific commodity experts. Research on cheese, ice cream, market milk, sweet corn, green lima beans, peanuts, and soybeans yielded both practical answers and new insights into these complex food systems.

Over the past 20 years, soybeans as a human food have been studied here extensively. The utilization of the whole or fractionated soybean as a beverage or as an ingredient in other foods has been emphasized. The University of Illinois has been a leader in this field.

Current research on the engineering and physical chemistry of food extrusion, on membrane technology in food and by-product processing, on bioreactors for utilizing agricultural by-products, and on the development of shelf-stable foods in the intermediate moisture range will be referred to as significant early contributions.

Agricultural Engineering

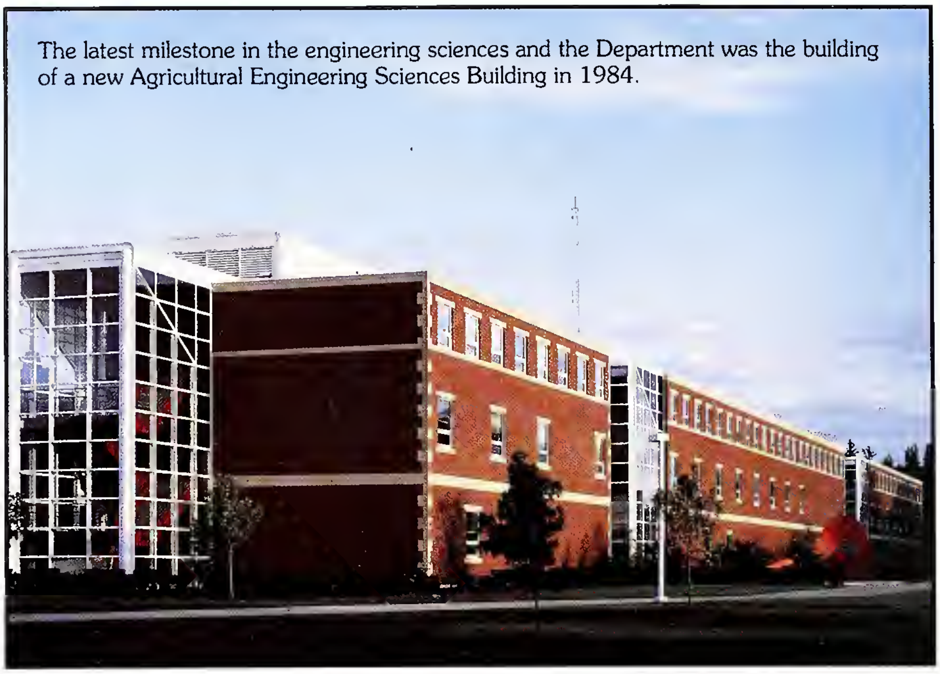
Engineering has always played a part in agricultural production and processing, in the life of a rural community, and in the well-being of a family. Early engineering was done, not by people educated in engineering and the physical sciences, but by innovative or mechanically inclined people who had a knack for building things. This phenomenon was certainly true in agriculture, where the local carpenter, wheelwright, or blacksmith and others engineered the barns and silos, the machines, and the homes to remove some of the drudgery from agriculture and rural life. Engineering was not identified as a program when the Station was founded, although the University had appointed a professor of agricultural engineering in 1870.

Early bulletins on engineering. A review of the Station bulletins shows that the first published on an engineering subject was written in 1901 about rural roads by Ira O. Baker of the Department of Civil Engineering. This is the first evidence of the cooperation between the colleges of Agriculture and Engineering that was to grow over the years. The next AES bulletins on Engineering were in animal production — one on silos by researchers in dairy husbandry and one on hog and beef housing by the staff of animal husbandry. These later bulletins dealt more with the conditions in the production facility and how they might have affected production than with the design elements for strength and environmental requirements, but they illustrate the nature of early research related to engineering.

Division of Farm Mechanics. In 1906, 6 years after the formation of the Division of Farm Mechanics in the Department of Agronomy, the Farm Mechanics Building was built on the "south" farm, with a door large enough to accommodate a threshing machine. For the next 15 years, faculty in and outside this division developed and improved field machines to enhance the production of crops. For instance, projects from 1913 to 1915 included: accuracy of drop in corn planters; calibration of seed drills; devices for accurate planting; influence of different types of cultivators on corn yields; cultivation as a factor in corn production; fuel economy of gasoline engines; distribution of farm motors; and relative economy of gasoline and kerosene as a fuel for internal combustion engines.

Departmental status. A milestone came in 1921, when Emil W. Lehmann was appointed head of the new Department of Farm Mechanics. Three research projects were initiated soon after its establishment: one to evaluate the performance of the new machines being adapted to new types of tractors; a second to improve the efficiency of threshing machines; and a third to improve farm health through improved sewage disposal.

A 1923 electric power survey conducted in Bureau County by Lehmann and Ray I. Shawl led to the initiation of one of the landmark research projects of the Department, the so-called Tolono experimental power line. This power line was built to evaluate the uses of electric power on farms and to demonstrate that electrical equipment could remove drudgery on the farmstead and


The latest milestone in the engineering sciences and the Department was the building of a new Agricultural Engineering Sciences Building in 1984.

n the home. Work on this project led o the introduction of electric lights and unning water on farms in Illinois. The ewage-disposal study, the power-use tudy, and subsequent studies by farm iousing specialists on space and house- iold environment requirements signifi- cantly improved family living on farms.

Department of Agricultural Engi- ieering. In 1934, 2 years after the Department of Farm Mechanics became he Department of Agricultural Engi- ieering, a curriculum was approved for a B.S. degree in agricultural engineering, and the first two degrees were awarded.

During the 1930s, when national attention focused on the Dust Bowl, agricultural engineers assisted Illinois armers in controlling erosion and im- proving techniques for water manage- ment. Other research dealt with methods to reduce costs and become self-sufficient on the farm as farmers spent much time and energy just surviv- ng the Great Depression.

World War II may have had more mpact on agricultural engineering than on any other area of agriculture. War- ime applications in electronics, radar, and other equipment brought a re- newed interest in this discipline. The war also produced new instruments that could make scientific measurements that formerly had been impossible. Also, computers were developed that did mathematical calculations which were previously too time-consuming. The result of these changes was an influx nto agriculture of engineers with the in- terest and ability to get solutions to long-standing and new problems.

By 1952, the research staff of the Station tripled in size and since then has made major contributions to knowledge about soil mechanics and tillage, spray nozzle design application and technology, tractor design and maintenance, and harvesting efficiency — including the basic studies on combines for corn harvesting. In electric power and processing, notable accomplishments were achieved in automatic equipment for feeding all classes of livestock, grain drying — particularly, corn — and the physical properties of crops relating to shipping, handling, and processing. Many of these accomplishments were achieved in cooperation with campus-based engineers in the Agricultural Research Service of the U.S. Department of Agriculture (USDA).

Emphasis on environmental quality by the public had a major impact on research on farm structures in this period, which led to pioneering studies on systems for handling wastes for all types of livestock raised in confinement. Other studies involved research on the remodeling of farm homes, on wood and concrete structural frames, and on building materials. Staff members cooperated with the wood science group of the Department of Forestry, which was studying the preservative treatment of lumber, the composition of particle boards, and roof truss design.

In soil and water resource management, large computers permitted the development of hydrologic and hydraulic models to characterize the process of erosion and overland flow. This work and studies on the design criteria for drainage and irrigation and on the impact of highway drainage on agricultural drainage systems have significantly affected the management of our soil and water resources.

A new building. The latest milestone in the engineering sciences and the Department was the building of a new Agricultural Engineering Sciences Building. Occupied in 1984, this facility brought together the programs of the Agricultural Engineering Department with those of the food engineering group in the Department of Food Science and of the wood science group in the Department of Forestry. This move is important because the challenges of the future are greater than those of the past. The easy problems have been solved. The future will require more than just more scientific expertise. It will require the efforts of research teams addressing complicated problems — like the current joint work of agricultural engineers and food scientists on food processing, agricultural waste management, and reducing harvesting and other damage to food crops. Educated as interdisciplinarians, agricultural engineers and food scientists expect to make major contributions to the engineering and food sciences in the next century.

Benjamin A. Jones, Jr., professor of agricultural engineering and associate director, Agricultural Experiment Station, and Joseph Tobias, professor of dairy technology, emeritus

In the Field

Lester V. Boone

Cyril G. Hopkin's early research in corn breeding involved improving the chemistry of the corn kernel itself — work that was without precedent in the history of plant breeding. Hopkins headed the Department of Agronomy from 1900 to 1919.

A theory remains a theory until it is proven to be fact or fallacy. It must be tested. Even after a theory may have been proven sound, questions often remain regarding its universality; this, too, must be tested. Across Illinois, there is marked variation in the environment in which agricultural crops are grown. Thus, it becomes necessary to test — under field conditions — crop and soil management concepts and products and the suggested practices derived from them.

The development of a new chemical compound in the laboratory or a new arrangement in the genetic makeup of a plant can hold dramatic potential for improving the efficiency of agricultural production. This improvement cannot be realized by producers, however, or by the ultimate beneficiary, the consumer of agricultural products, until the product or concept has been evaluated in the field.

Changing one management practice often has an effect upon others. A new variety of oats, for instance, may require a different seeding date, fertilizer rate, or plant density for optimum production than did the variety it replaces. Although we can speculate, no conclusions can be drawn until we do the field studies.

Hopkins's vision and legacy. Agricultural science was young in the latter part of the 19th century. A few farsighted individuals, however, were interested in examining the scientific aspects of farming. Although Rotation Experiment Number 23, which became the Morrow Plots, had been begun by George E. Morrow and Manly Miles in 1876, and the first off-campus research facility had been established near Edgewood in 1896, it was not until Cyril G. Hopkins was appointed head of the Department of Agronomy in 1900 that a major effort was made to establish "experiment fields" at locations around Illinois and to conduct site-specific field research in soil and crop management where the soils, climate, and farming systems were unique.

His orientation. Hopkins was an agricultural chemist, who came to the Illinois Agricultural Experiment Station in 1894 and (while head of the Department of Agronomy) became its vice-director in 1903. He was a brilliant, dedicated man — a "workaholic" long before the term was coined.

He wanted the Agronomy Department to serve the citizens of Illinois in the most effective way. He perceived that Illinois needed an inventory of its agricultural resources and so instituted the most comprehensive soil survey that had ever been attempted. He saw further the need for a system of research facilities supporting experiments to determine the best methods of soil management and crop production and to demonstrate these methods to farmers.

Hopkins knew that it was impractical for farmers to do their own research.

But there's more

In addition to the work conducted by the Agronomy Department at outlying experiment fields, several other units within the College also use remote sites around the state.

For example, Forestry Department research began in the 1940s with a project on management techniques for southern pines. This program has expanded to include research on forest soils; ecology of pine plantations and conservation; genetic development of cottonwoods; and agroforestry.

AES horticulture research at remote sites involves food crops, mainly vegetables and small fruits. In general, this work includes tests of cultural practices and pre-release variety trials. For example, over 40 varieties of sweet corn are being grown to collect yield data and measure insect resistance; new varieties of blueberry are being tested for high-pH tolerance; variety selection and production practices research are being conducted on sweet corn, peppers, tomatoes, melons, and coles.

Other recent work includes an insecticide rotation study for corn rootworm and a demonstration plot for European corn borer (agricultural entomology) and a corn nematode research project (plant pathology).

Speaking as "Percy Johnston," a knowledgeable farmer, he described at least a part of his rationale in his book *The Story of the Soil* (1911):

> *As for me, I purpose making no experiments whatever. I do not see how I or any other farmer can afford to put our limited funds into experiments, especially when we often lack the facilities for taking the exact and complete data that are needed.... I think this is public business and it is best done by the State for the benefit of all.*

The system's beginnings. As remarkable as it may seem, during Hopkins's 19-year tenure as head, the Department established 53 facilities for field research, and all of them, except for the Urbana South Farm, were located off campus. These facilities had a dual role: first, to prove whether or not crops grown on the various soil types would respond to the rotation of crops and to the application of limestone, animal manure, phosphorus, and potassium; and after these facts were proven, to demonstrate these effects to farmers so that they could improve their soil and crop management practices.

From the start, these fields had a dual research-extension mission. Locations were carefully selected, not only to sample the soils and climatic conditions but also to make them accessible to as many farmers as possible around the state. Hopkins asserted that the fields should be located as to allow any farmer in the state to visit one (by horse and buggy) and return home the same day.

The system evolves. After the Palestine field was established in 1919, the year of Hopkins's untimely death, no other field facilities were established until the 1930s, when the Dixon Springs Agricultural Center (1934) and the Brownstown Agronomy Research Center (1937) were established. The size and missions of these two facilities reflected evolutionary changes taking place in agricultural technology, ease of travel, and experimental technique.

Although the earlier "soil experiment fields" were small (about 20 acres each) and their research projects relatively unsophisticated, these new centers were larger and were laid out to accommodate a greater number of more varied and more scientifically designed experiments and demonstrations. However, the philosophy regarding their location and mission remained unchanged — basic and applied research and demonstration work on crop production and soil management, scattered widely enough to sample diverse environments and be accessible to farmers in all regions of the state. This philosophy persists to the present day in the form of the Department of Agronomy's "Six Coordinated Centers" (6cC).

The last "experiment field" established by Hopkins was not closed until 1982 when it was decided that the work being done at the Toledo field could more effectively be conducted at the Brownstown Center. Thus an era ended. In reality, however, nothing ended; but one more step was taken in the evolution of the system. A step that Hopkins would probably have taken earlier, had he lived.

The evolution of the system that was begun with the establishment of the Brownstown Center, on Cisne and Wynoose soils in the "Claypan" region, and the Dixon Springs Center, on Grantsburg and Belknap soils in the "Ozark Uplift" region with its associated bottomlands, continued slowly — as evolution often does.

The Northern Illinois Agronomy Research Center was established on Drummer and Flanagan ("Cornbelt") soils near Shabbona in DeKalb County in 1948; and in 1960 the Northeastern Illinois Agronomy Research Center came on-line in Will County near Elwood (on Ashkum, Elliott, and Blount soils in the "Wisconsin till" region). After a pause to consolidate gains and to develop resources, a tract of Clarksdale, Keomah, and Orion soils in the rolling, deep-loess land of Pike County was acquired for the Orr Agricultural Research and Demonstration Center in 1978, followed 2 years later by the Northwestern Illinois Research and Demonstration Center located on Tama, Muscatine, and Sable soils in Warren County.

In 1985, the Department of Agronomy assumed responsibility for the Illinois River Valley Sand Field, which is located on Plainfield and Bloomfield (sandy) soils in Mason County and which had been operated by the Department of Horticulture. Due to budget constraints and other factors, the Northeastern Illinois Center near Elwood was closed at the end of the 1987 season.

Over the years, these facilities have been the sites for the evaluation of any number of concepts, procedures, and products. Virtually all agronomic technology that has been developed over the last century has been tested at one or more of these fields and centers. Hybrid corn, nitrogen fertilization, soil testing, zero-tillage, herbicide usage, crop rotation, erosion control, variety development; all these and many more technologies were developed, tested, and improved through projects conducted on these experimental fields and centers.

These off-campus facilities have always been supervised by staff members of the Department of Agronomy who live in the region and become a part of the community. When most of the experiment fields were small and the work relatively unsophisticated, each area agronomist (often referred to as a "fieldman" in the early years) had the responsibility for five to seven fields and established a home and headquarters somewhere in the midst of them, thus providing direct access to the University and the Department right in the local community.

A brief, informal history such as this would be incomplete without mention of far-reaching developments, outstanding individuals, and watershed events of the system. Quite simply, this system was the brainchild of Hopkins. In a very real way, it is still his system. He conceived and established it; and during the nearly 70 years since his death, it has run on the momentum he provided.

Other pioneers and leaders. Of course, a number of other outstanding individuals have been involved, and some of them should be mentioned here. The austere scholar Frederick C. Bauer was one. Alvin L. Lang, with his touch of flamboyance was another. Lawrence B. Miller, whose career was largely "unsung," was a bookkeeper, coach, and conscience of the group for over 40 years and probably did more than anyone else to maintain the momentum created by Hopkins.

George E. McKibben, the "father of zero-tillage," did his pioneering work at Dixon Springs. Derreld L. Mulvaney, the northern Illinois area agronomist for more than 30 years, epitomized the genre. John W. Pendleton, coordinator during the 1960s, modernized and upgraded the professionalism of the system and its people.

There was also the legendary P.E. (Pat) Johnson — fieldman, area agronomist, and superintendent of the Brownstown Center — who undoubtedly had more influence than any other individual on the improvement of soil and crop management in the "Claypan" region of southern Illinois. He not only represented the University to the people of that region but, in a very real sense, to many of them he and the experiment fields were the University.

Although agronomic science has broadened and deepened dramatically in recent years and many of the current frontiers are at the cellular and molecular level, these field facilities are still functioning, because it is still true that new concepts, products, and practices cannot be accepted and used until they are tested in the field.

Lester V. Boone, agronomist and coordinator of the statewide research centers, Department of Agronomy

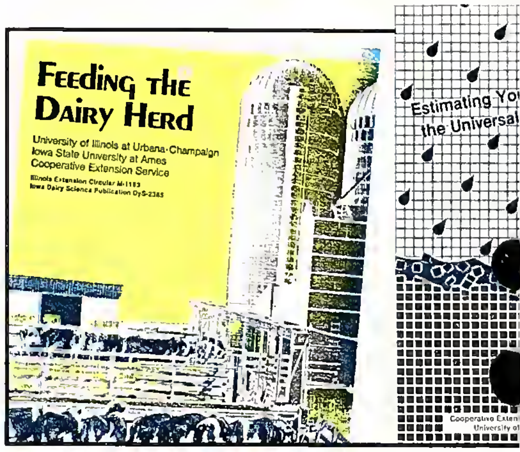
- **Former experiment fields**

Current agronomy centers

❶ Northern Illinois Agronomy Research Center (DeKalb)
❷ Northwestern Illinois Agricultural Research and Demonstration Center (Monmouth)
❸ Illinois River Valley Sand Field (Kilbourne)
❹ Morrow Plots, South Farm (Urbana)
❺ Orr Agricultural Research and Demonstration Center (Perry)
❻ Brownstown Agronomy Research Center (Brownstown)
❼ Dixon Springs Agricultural Center (Simpson)

Research and Extension

Peter D. Bloome



Our celebration of the 100th anniversary of the Illinois Agricultural Experiment Station (AES) presents a most appropriate opportunity to reflect upon how the vital linkages between agricultural research and Extension have contributed to the development of human potential and improved the quality of life for all Illinoisans.

The primary missions of the Illinois Cooperative Extension Service (CES) are the dissemination and application of research-based knowledge. That knowledge, in turn, leads to more informed decision making by individuals, organizations, and communities.

All Extension educational programs are based upon research. Part of the genius of the land-grant university system, however, is that Extension not only flows naturally from research, it also directs it. While encouraging people to apply University research on their farms and in their homes and communities, Extension gathers information about people's concerns and returns to the University with researchable ideas for new knowledge that will ultimately benefit us all.

The benefits of research and Extension. Academicians and administrators can extol the wisdom of the land-grant system and the importance of strong research-Extension linkages. But the strongest endorsement comes from those who benefit directly from that genius.

Larry A. Werries, director of the Illinois Department of Agriculture, for example, points to dramatic increases in agricultural productivity from research and Extension: "The land-grant university system — with its three-pronged approach of teaching, research, and Extension — is unique to this country. Coupled with good old Yankee ingenuity, this system has propelled the U.S. farmer to unimagined heights in terms of productivity."

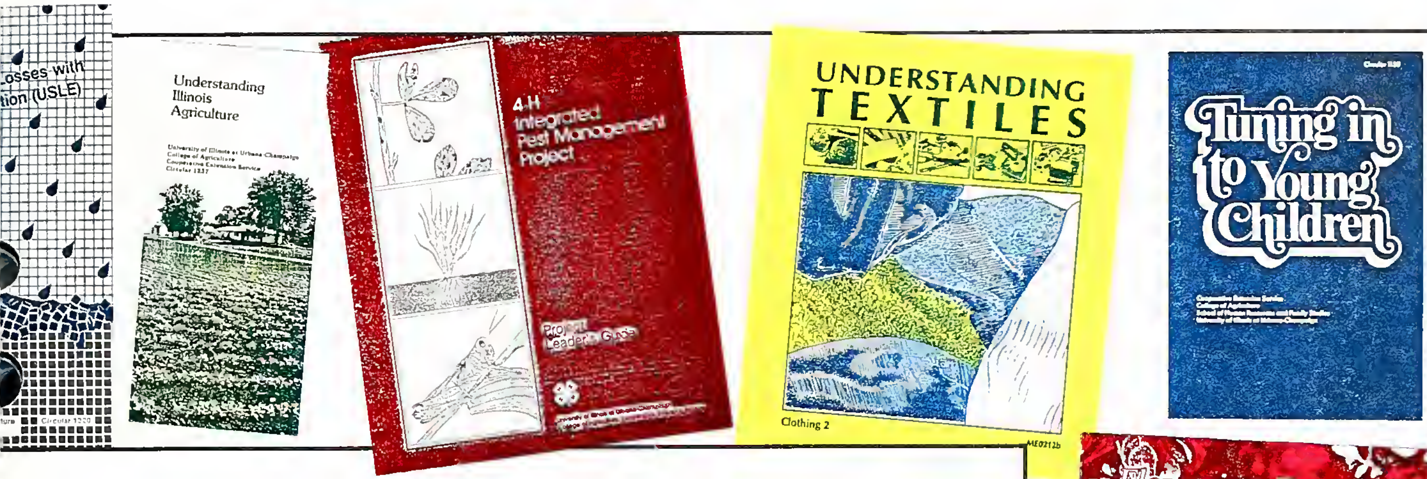
Harold W. Dodd, who has seen Extension and research at work both as a farmer and as president of the Illinois Farmers Union, has said, "It is now easier for me to grow 150 bushels of corn and 50 bushels of soybeans to the acre than it was to grow 65 bushels of corn and 25 bushels of soybeans when I moved to my Sangamon County farm 42 years ago." He attributes much of this success to agricultural research and adds, "Equally important is the dissemination of those research results to the practicing farmer through the Extension Service." Increased productivity, however, has been a mixed blessing. According to Dodd, "The consumer has been the true recipient of this production success in the form of cheap food, while it has made it possible for farmers to produce themselves into bankruptcy."

The experience of advisers. CES advisers are quick to acknowledge their dependence on research. Donald E. Meyer, McLean County Extension adviser in agriculture, notes the importance of the AES for evaluation and adaptation of new technologies: "This unbiased research-based information is what people will continue to demand. Without the Agricultural Experiment Station to help us sort out facts, we would have problems." Beatrice H. Bagby, assistant director and state leader for Extension home economics programs, agrees: "Research is what gives Extension a unique niche. It provides the base for maintaining our ability to respond to clientele with the most current, cutting-edge information and to meet their problem-solving needs."

Extension advisers are likewise quick to identify specific research results that have had a direct impact on people's lives. John A. Church, Kendall County Extension adviser in agriculture, cites research in integrated pest management, crop varietal improvement, plant disease control, soil fertility, and livestock housing and nutrition as examples. Cheryl L. Bielema, Pike County Extension adviser in home economics, points to food-preservation research conducted by Mary A. Keith, specialist in foods and nutrition, as having immediate, direct impact on Extension clientele. Bielema also cites the efforts of Catherine A. Surra, Karen L. Davis-Brown, and Sonya B. Salamon of the School of Human Resources and Family Studies. Their research provided the model from which Extension home economists developed the action plan for "Empowering Rural Families and Communities." This program encouraged a number of rural citizens to prepare testimony for Lieutenant Governor George H. Ryan's Task Force on the Future of Rural Illinois.

Robert W. Frank, Jackson County Extension adviser in agriculture, believes that to meet the needs of people from all areas of the state, Extension must incorporate, verify, and disseminate research results from a variety of sources and help users interpret their significance: "Research by one university to try to meet all needs is neither practical nor cost effective. Along with the release of new research-based results, farmers also like information on cost effectiveness and the risks involved."

The achievements of research. Extension and research continue to make a difference in the lives of Illinois citizens today. But the observance of the centennials of both the Hatch Act



— the federal legislation that established agricultural experiment stations in 1887 — and the creation of the Illinois Station in 1888 provides an opportunity to reflect upon the important research accomplishments of the past as well.

Ellen I. Burton, Woodford County Extension adviser in home economics, points to poultry research that enabled homemakers of the 1930s to supplement family income by raising small flocks. Likewise, horticultural research enhanced the Victory Gardens of the 1940s. More important, in Burton's belief, however, is that research from the experiment stations helped farm families improve their economic positions within their communities: "As their educational awareness increased, so did their desire for greater education and career opportunities for themselves and their children."

"We sometimes forget the tremendous progress made through research over the years," notes retired Sangamon County Extension adviser Denver C. Corn. Aware that without the development of hybrid corn in the late 1930s and more recent research that led to the control of southern corn leaf blight, there might not be a corn surplus today, Corn comments: "This abundance should be a blessing to mankind. It's unfortunate when too much food becomes a curse in a hungry world."

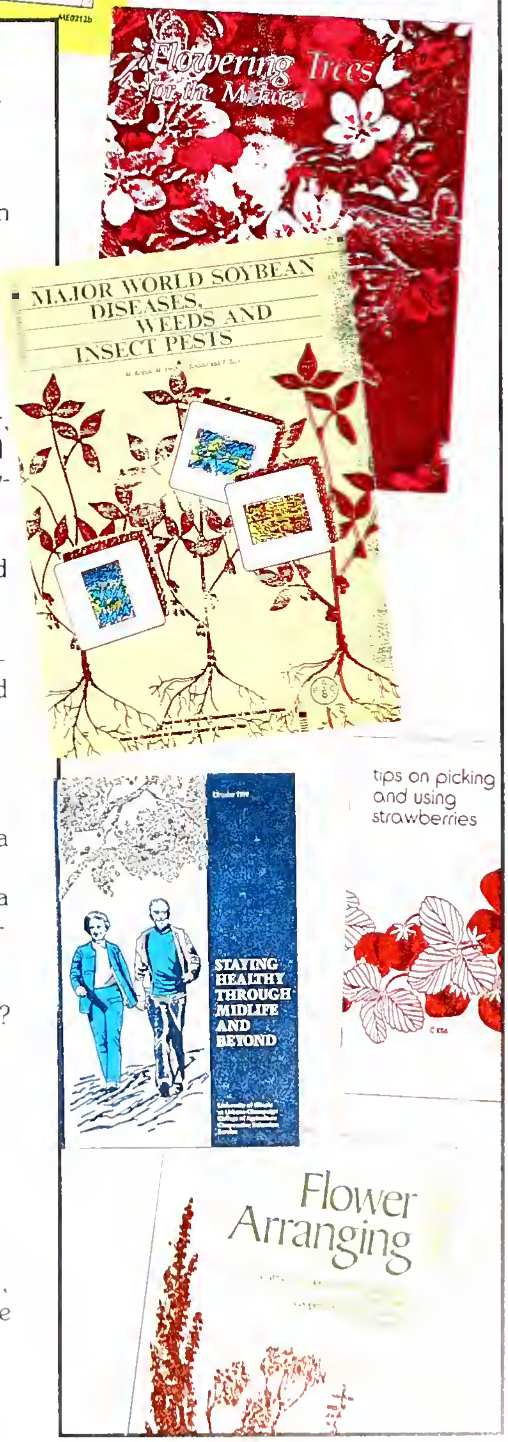
Retired Gallatin County Extension adviser Earl M. Lutz remembers the impact of pioneering no-till research conducted by agronomist George E. McKibben at the Dixon Springs Agricultural Center and the Extension system that disseminated McKibben's results: "Farmers came, they saw, they adopted. In the mid1960s, George attempted the unbelievable — double-cropping soybeans in wheat stubble. What began as an idea in George's mind has now been adopted by almost every farmer in southern Illinois."

Lutz also recalls how a crisis that affected area farmers accelerated research that continues today: During the late 1940s, Gallatin County farmers grew white corn as continuous corn in the lower Ohio River bottoms until northern corn rootworms created an emergency situation. Educational programs conducted by John H. Bigger, an entomologist with the Illinois Natural History Survey, made a difference, however. "Farmers did a better job using available knowledge," Lutz says. "And John and fellow researchers accelerated the study of rootworms, work that has continued to this day."

The importance of research to Extension efforts is perhaps most appreciated when it is absent. Extension staff who have worked in other countries can attest to that. After retiring, Macoupin County Extension adviser Orville O. Mowery accepted an assignment in India with the U.S. Agency for International Development. While there, he found "a big gap in research, which greatly hampered progress in Extension."

Extension and research share a proud tradition. But what of the future? Werries foresees "two great challenges for agricultural research: helping farmers become low-cost producers and helping industry develop new and expanded uses for this nation's largess." The effectiveness of Extension in the future will continue to depend on well-targeted and well-directed research. In Lutz's words, "Like ripples in the ocean, who can predict the bounds of influence from research?"

Peter D. Bloome, assistant director, Cooperative Extension Service



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Illinois Research

Summer 1988

The Human Environment

Illinois Research

Agricultural Experiment Station
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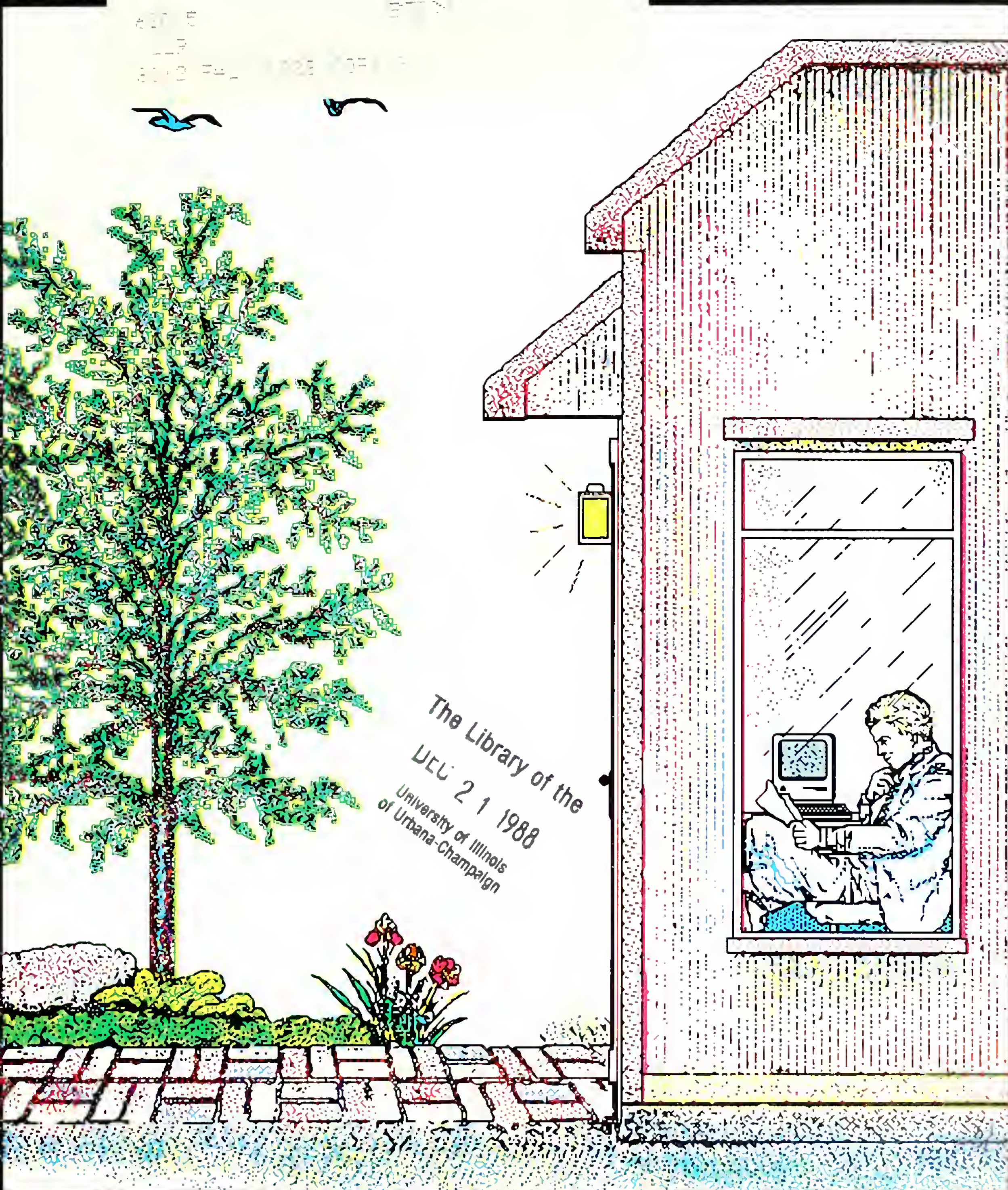

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 30, Number 2

The Cover

The human environment created by this home and yard was drawn by our graphics director with Claris's *MacPaint* 2.0. Final output was produced using Quark's *XPress* 2.0 and printed on the Linotronic 300 at actual size.

"At a time unlike any in the past, we must envision the future."

Illinois Research

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John R. Campbell

Scholar, Educator, Author, Administrator

After 11 years as an administrator in the University of Illinois College of Agriculture, Dean John R. Campbell left in early August to become the president of Oklahoma State University. Born and educated in Missouri, Dean Campbell became a member of the Dairy Science Department of the University of Missouri in 1960. Widely recognized for his outstanding teaching, he quickly rose to the rank of professor. In 1977, he joined the University of Illinois as associate dean of the College of Agriculture and director of resident instruction. In 1983, he became the ninth dean of the College of Agriculture.

Dean Campbell made many important contributions to the University of Illinois College of Agriculture. He is perhaps best known for creating the Jonathan Baldwin Turner (JBT) scholarship program, which has grown dramatically and now provides about seventy $2,500 scholarships each year to outstanding students. Recently expanded to include graduate students, the JBT scholarship program is entirely privately funded. This very successful program has enabled the University of Illinois College of Agriculture to attract the finest students and has been emulated by many other states.

Dean Campbell will also be remembered for the unprecedented building program that developed under his leadership. Major capital programs initiated include the recently completed Plant Science Laboratory, the addition to the Animal Science Laboratory, the Plant and Animal Biotechnology Laboratory, the Agricultural Sciences Information Center, the animal research unit at the Orr Agriculture Research and Demonstration Center, the Sponsored Research Incubator Building, the remodeling of the old Dairy Manufacturers Building into the Agricultural Bioprocess Laboratory, the remodeling of the old Veterinary Medicine Building into the National Soybean Research Laboratory, and the Imported Swine Germplasm Research facility. These projects are transforming the agricultural campus into one of the finest research and educational facilities in the world. When completed, they will cost over $100 million.

Dean Campbell also worked to create the Center for Value-Added Agriculture, which receives $500,000 each year in recurring state support. Under his leadership, the College has built an unusually strong program in plant, animal, and microbial biotechnology; has recruited a large number of outstanding young faculty; has sharply increased its ability to compete effectively for outside support; and has improved the salary levels of agricultural faculty and staff relative to other units in the University of Illinois and to counterparts in other institutions.

John Campbell's activities as dean have been characterized by his enormous energy and enthusiasm, his strong emphasis on quality education, and his relentless quest for excellence in research and extension. One of his most important contributions has been establishing a strong network of supporters among agricultural and home economics alumni, agricultural organizations, commodity groups, the agribusiness community, and consumers of agricultural products. These supporters have vigorously promoted the causes of agriculture and home economics and of the College of Agriculture, including the building projects and programs outlined above, and have provided valuable input into all activities of the College.

Dean Campbell, we hate to lose you, but we wish you the best as you assume new responsibilities in your role as president of Oklahoma State University. Thank you for all you have meant to us. — The Station

Illinois Research

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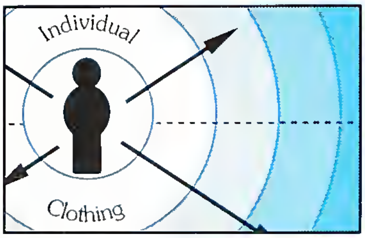
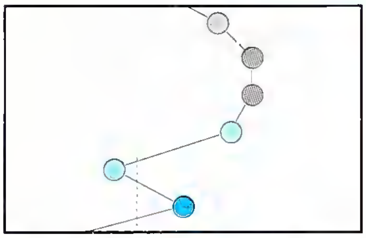
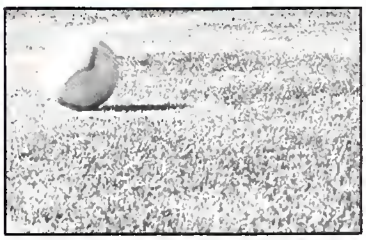






The Human Environment

Enhancing the Quality of Life: Recommitment to the Goal

All predictors indicate that human environments will continue to change and that the changes will be dramatic. Change occurs as we develop and make choices about our roles in life. Greater diversity in family composition and increasingly more complex networks of human relationships are emerging. Rapidly changing economic conditions are also a feature of contemporary living. These changes require continuous study as we seek to understand their dynamics.

Historically, people in the United States have highly valued privacy in family matters and freedom of individual choice. Although these fundamental values have fostered a favorable human environment for most citizens, they have allowed public policy and governmental programs to lag behind changes in our lifestyles. Recent legislation to enforce payment of child support is an example of public policy trying to catch up to the reality of family life today. The effectiveness of other family-related public policies, such as child care and family and medical leave, must also be studied.

Housing experts predict that our homes will change more in the next 20 years than they have in any equivalent period in the history of home building. These changes will be precipitated by demographic changes — primarily the dramatic increase in the proportion of elderly and the maturing of the "baby boom" generation, by changes in the size and composition of households, and by extreme differentials in ability to pay for housing, as well as by changes in materials and technology. Research is needed to discover the best alternatives for creating a favorable human environment while meeting our need for shelter, leisure, and beauty.

Researchers must be constantly alert to the emergence of new concerns about human relationships, health, safety, and the management of personal resources. Researchers who understand the human dimension of issues that appear to be simply technical problems can contribute to solutions that are more likely to be adopted. The studies of protective clothing for use by pesticide applicators is an example. We probably will see more interdisciplinary collaboration among scientists as we study the relationships between people and their physical environment. The importance of all of these issues calls for a recommitment to the goal of enhancing the quality of life in the human environment.

Sharon Y. Nickols, professor and director, School of Human Resources and Family Studies, and assistant director, Illinois Agricultural Experiment Station

The Human Environment: People, Places, and Relationships

Sharon Y. Nickols and Leann L. Birch

The human environment is comprised of people's interactions with each other and their physical surroundings. Because these encounters are so familiar and mundane, they often are taken for granted, but the human environment has a tremendous influence on personal and societal well-being. The complex interactions among social and physical elements of this environment essentially determine the quality of life experienced by individuals. This issue features important current research that sheds light on these relationships.

The accompanying figure depicts the social and physical fabric of the human environment. In social relationships, the most immediate environment is the family; more distant is the social network including co-workers, peers, voluntary organizations, and other groups, and finally, the larger socio-economic, political, and cultural environment.

Our most intimate physical environment is our clothing. Next in proximity come our housing, workplace, neighborhood, and finally the community. These are all experienced in the context of the natural environment. The interrelationships among elements in the concentric circles are complex. The physical aspects of the environment, moreover, cannot really be separated from the social. For example, the physical arrangement in a house or office influences the interactions among family members or co-workers. Governmental policies, local customs, and economic conditions influence the priority given to parks and public green spaces, as well as neighborhood zoning regulations. These facilities and regulations in turn affect the quality of life of individuals and families.

Relating to others. In our society as in most others, the family is the fundamental unit for social and economic organization. The family procures resources, then develops and allocates them in order to meet the basic human needs for shelter, clothing, food, and nurturance. The family is also charged with the enormous responsibility for producing and socializing each successive generation. The family itself comprises a critically important aspect of the human environment because children experience their crucial first relationships with others in the family. The quality of these relationships, in turn, shapes their social and cognitive development, including self-concept, values, attitudes, and ability to cope with change. Ideally, within the family, individuals can depend on each other for emotional, as well as economic support.

In recent tumultuous times, social and economic changes in the United States have been an impetus for departures from the family form in which the father is the breadwinner and the mother is a homemaker. In 1985, less than one-fourth of families fit this profile. The number of families headed by women has dramatically increased: about 20 percent of all families with children are now headed by a woman. Currently, more than one-half of U.S. women are in the labor force, and it is estimated that by 1990 more than one-half of mothers with children under 6 years of age will be employed outside the home. As an institution, the family has survived downturns in the economy, changes in societal beliefs regarding women's roles, and revisions in public policy relating to children and families.

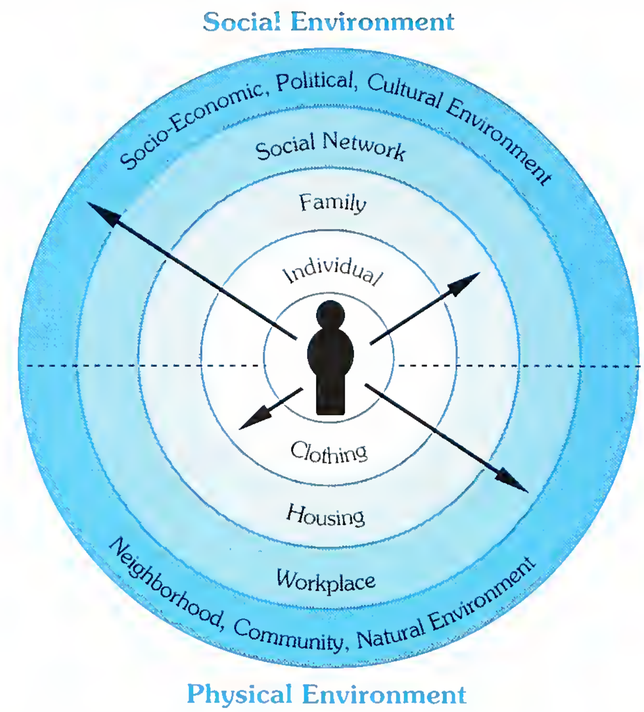
In response to these pressures, the form of the family has changed and become more diverse over time.

However, individual families have not always coped successfully with these changes and the stress they can bring. Headlines and cover stories reflect concern about rapidly changing expectations for employment among men and women, geographical mobility, technological developments affecting family planning and career choices, marital dissolution and subsequent blending of households through remarriage, the increase in single-parent households, and the crisis in child care. News media coverage is but one indicator of the importance of these issues.

Research is beginning to reveal how families are adapting to these rapid social and economic changes. The results of such research also suggest ways to maximize the quality of life in the face of these changes. New sources of social support created to replace lost family support or to supplement the support from relatives can assist families in critical times of transition, such as divorce. Changes in public policy, such as legislation affecting child support, are aimed at reducing the financial and emotional stress experienced when parents divorce.

Public opinion polls show that Americans highly value family life. The family will continue to be the primary social institution in the human environment. However, ours is a complex society, and there are many other contexts for human interaction, such as the workplace, school, community organizations, and recreational facilities. Well-designed and well-executed research studies of interpersonal relationships, individual development, and household-family decision making are necessary to provide a better understanding of our increasingly complex social environment. This information can form the basis of much needed social policy on children and families.

The Complex Fabric of Our Human Environment



Interacting with our physical surroundings. The "built environment" — the structures in which we live, the clothing we select for protection and adornment, and the recreational areas we create — are important elements of the human environment. In the United States, we create a large part of our physical environment, in contrast to the situation in developing countries, where elements in the natural environment, such as soil, water, and terrain predominate. The near environment of clothing and housing affords much more than physical protection for human beings. It reflects the values of those who create and use it.

Clothing. To a large extent, people can control the effects of their physical environment through the choices they make about clothing. A catalog from a very successful clothing retailer recently proclaimed: "Clothing is shelter." This is particularly true of clothing worn for protection against natural environmental factors, such as the sun or wind, but it is also true of clothing worn for protection against chemical agents used in the production of agricultural products and the care of our lawns. Clothing provides more than protection, however. It is a statement about ourselves, and consequently has an influence on how others respond to us. This, too, is part of the human environment.

Housing. Choices about housing and furnishings reflect a family's tastes for housing versus other types of consumption. These choices indicate how a family intends to use its resources, for example, to provide simple functional living space or room for entertainment or business. These choices affect the type of human interaction that will occur in a house.

The house, its furnishings, and surroundings create a sense of relatedness among its occupants as they interact within the context of their physical space. Memories of the best of family times are often associated with particular locations in a house — the coffee table near the fireplace, where the family works on jigsaw puzzles; a favorite easy chair, where one snuggles up to read a book; the kitchen table, where the family discusses controversial topics.

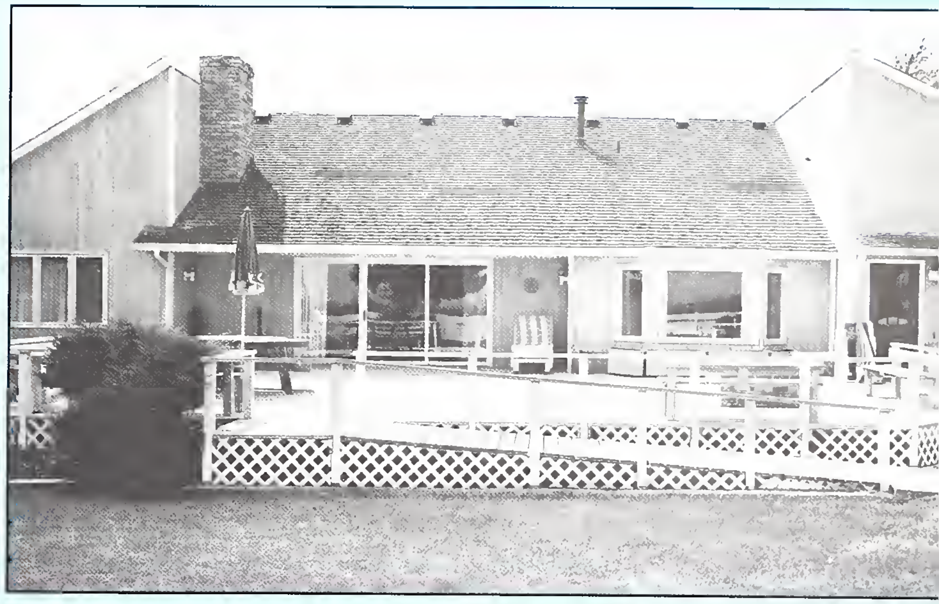
The furnishings of the house often are a physical manifestation of the link between generations in a family. Treasured heirlooms and well-worn furnishings enhance the physical environment

with a human presence because they evoke memories or stories of ancestors who used the items in the past.

Research into the interaction between people and their physical environment can help create more pleasing and functional spaces for living. For example, time and motion studies conducted in the 1930s paved the way for standardization of kitchen and laundry facilities, thus reducing the drudgery of doing household work. Energy studies contributed to recommendations for retrofitting houses to make them more energy efficient. Likewise, research plays an important role in improving the safety of human beings working in hazardous environments.

A challenge to the reader. Comfortable surroundings and harmonious personal relationships can lull us into a sense of complacency about our environment. The physical and social elements of a pleasing human environment can be so taken for granted that their maintenance is neglected. Investments of time, energy, and money are needed not only to maintain but also to improve the human environment. Have you taken a careful look at your total environment lately? What do you cherish and plan to maintain? Do you fully understand what you need to know to achieve this goal? What must be changed to improve the quality of your life?

Sharon Y. Nickols, director, School of Human Resources and Family Studies, and assistant director, Illinois Agricultural Experiment Station, and Leann L. Birch, professor of human development and chair, Division of Human Development and Family Ecology



The complexity of our human environment is derived in part from the diverse needs of the individuals in it. In making choices about the buildings in which we live and work, pleasing architectural design does not have to be sacrificed for the sake of its function. Illustrating the harmony that planning creates between form and function are the deck on this home (above) and one of the north entrances to Mumford Hall at the University of Illinois at Urbana-Champaign (below) — both designed with the special needs of people with disabilities in mind. Lowering physical barriers for the disabled improves the quality of life for all. The first major college campus to offer comprehensive education to the disabled, the University of Illinois has made virtually all of its buildings and programs accessible to them.

Social Contexts of Adolescents: A World Unto Themselves

Reed W. Larson

Asked whether they would ever like to be adolescents again, U.S. adults in a recent survey responded with a nearly unanimous, "No!" Few people desire the experience of the lead character in the movie, *Peggy Sue Got Married*, who returns to relive some of the ups and downs of her teenage years. The idea that we are a youth-oriented society is a myth: most of us are glad to be rid of the awkward and sometimes painful years of adolescence. But were they really that bad? Have we, like Peggy Sue, remembered only part of the story and forgotten many of the warm and exciting moments?

Far from being a youth-oriented society, U.S. society is preoccupied with the affairs of adult life: jobs, personal leisure, and the immediate needs of the family. Our lives proceed at a rapid pace that leaves little time for remembering what we felt when we were young or for trying to understand the experience of teenagers today. Young people are shuttled off to school and have remarkably little personal contact with adults other than their parents. The problems of adolescents — unwanted pregnancy, delinquency, and suicide — get blamed on youth or their parents with little attempt to understand the total environment or situation we create for them.

Seeing through their eyes. My research is aimed at getting adolescents' accounts of their lives in order to see the world as they do: to find out what they feel when they get up in the morning, what they experience in school, and how family life looks from their side of the dinner table.

To do this, my colleagues and I have asked young people to provide periodic reports about what they experience during a week, using a procedure we have called the "Experience Sampling Method." We performed a large study of suburban Chicago adolescents that was funded by the National Institute of Mental Health. One participant was a kind, seventh-grade boy, whom I will call Selman. He was asked if he would be willing to carry an electronic pager for one week and to report on whom he was with, what he was doing, and how he felt 8 times a day when signaled by the pager. Selman, like 500 others involved in the study, was enthusiastic about taking part. He obtained permission from his parents, and we instructed him on the fine points of our procedures. One week later he had completed the study and returned the pager along with his booklet of self-reports about his activities and feelings, which are summarized in Figure 1.

Quickly fluctuating moods. During the very first signal, Selman was in a typical seventh-grade situation: while changing clothes in the locker room, he was arguing with a friend over who was better. He reported feeling angry, awkward, and "hyper." But his mood quickly recovered: about an hour and a half later in English class, he was happy and cheerful. Much later, at 5:50 p.m., however, he felt tired and bored, watching a basketball game; but at 6:40 p.m., when riding home on the bus, he felt energetic again because he was with friends, and they were joking.

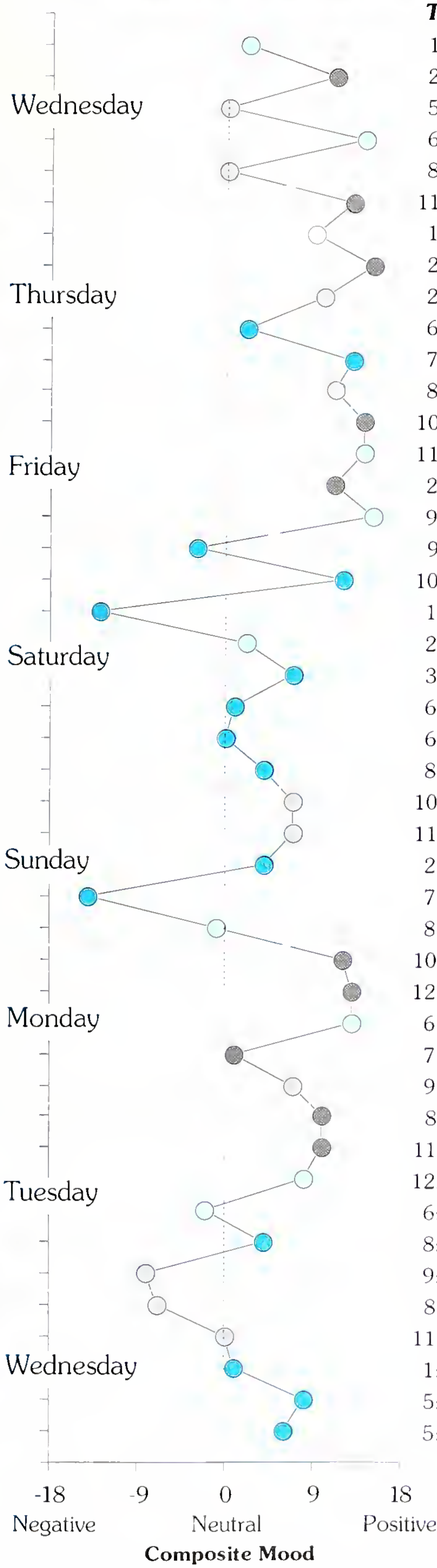
Thursday and Friday were good days for him. On Thursday he got an A on a social studies test. On Friday, there was an important basketball game. Unfortunately, the demands of the game required his turning off the pager during play. Saturday, however, was dismal. His older brother pressured him into playing football, Notre Dame lost a big game, and he had to babysit for his 4-year-old brother.

Selman's week continued to go up and down like a roller coaster. He felt great about being with friends and about success on a science test but was down when he locked horns with his brother and when he felt exhausted. This emotional variability, we have found, is a characteristic that distinguishes adolescents' experiences from those of most adults and also from those of preadolescent children. During the same week, we also arranged for Selman's parents to report on their moods, which were not nearly as variable. Teenagers' moods are more extreme and change more quickly — perhaps as a result of the dramatic biological, social, and cognitive changes associated with adolescence.

"The idea that we are a youth-oriented society is a myth..."

Relating moods to social contexts. What has been particularly interesting to me is how these fluctuating moods appear to be related to adolescents' social environments. Certain

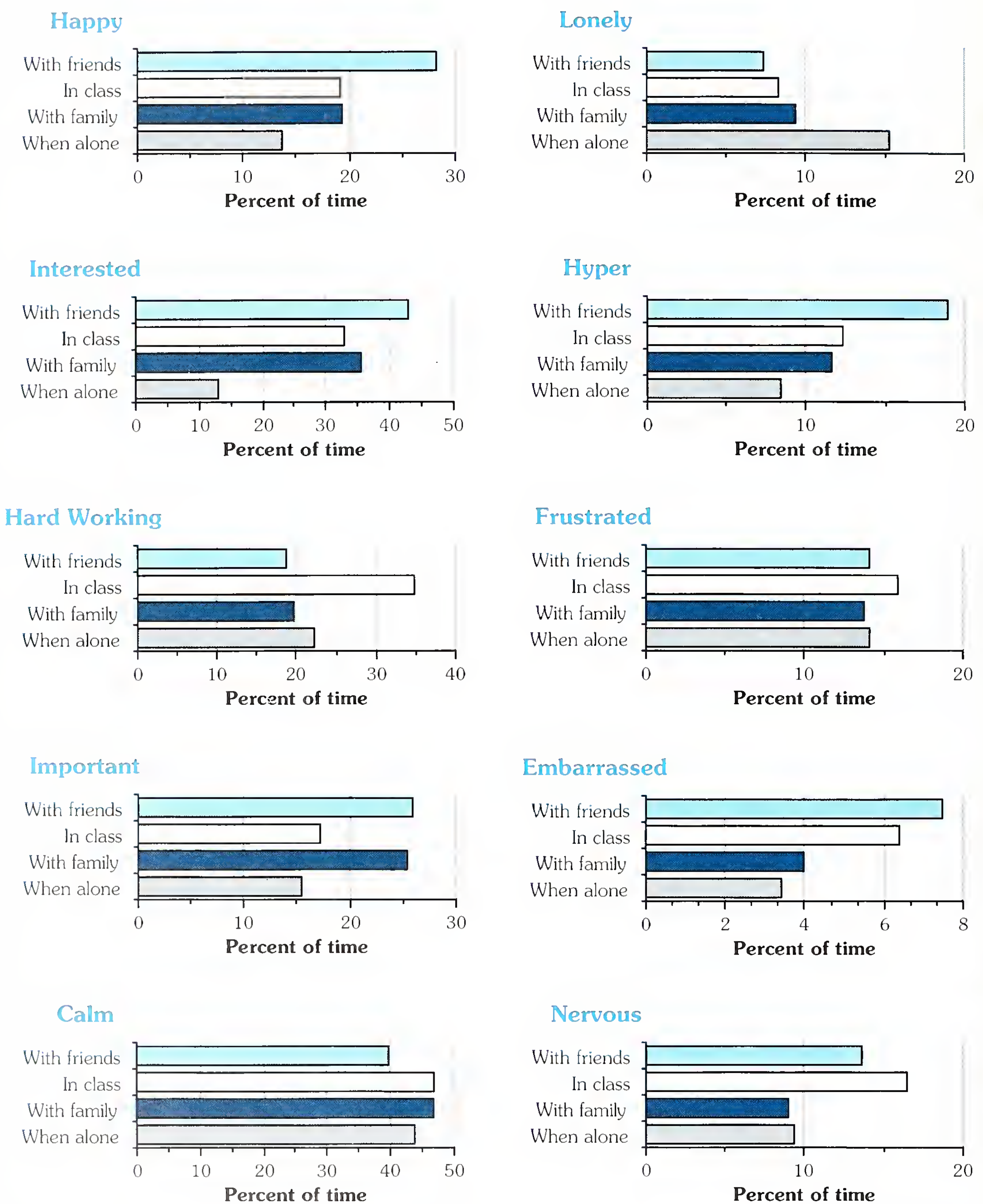
Figure 1. A Week in the Life of a Seventh-Grade Boy

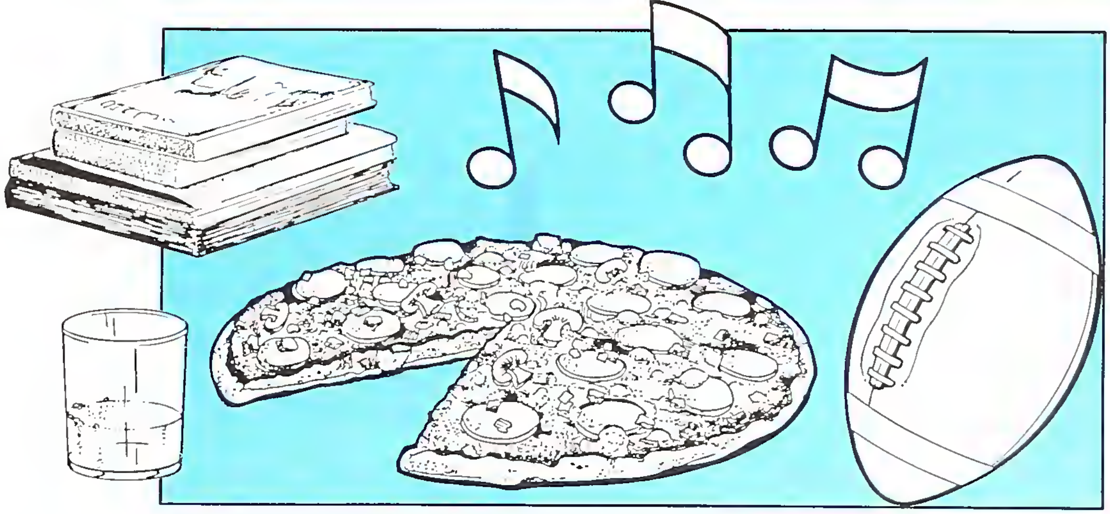


Time	Activity
1:12 p.m.	Changing clothes in locker room; angrily discussing "who's better"
2:57 p.m.	Moving seats in English class
5:50 p.m.	Watching the eighth grade's basketball game in school gym
6:40 p.m.	Discussing on the bus how bad the Mets were
8:13 p.m.	Watching the movie, "Airplane," on TV at home
11:15 a.m.	Grading an assignment on scientific notation in math class
1:17 p.m.	Asking a teacher in the hallway for permission to get a pencil
2:06 p.m.	Taking a science test on vertebrates; excited about big game after school
2:28 p.m.	Watching TV; thinking about tomorrow
6:21 p.m.	Scoring touchdown in living room; sorry for having to play with brothers
7:40 p.m.	Happily playing a game with my brothers
8:15 p.m.	Doing math problems in room
10:06 a.m.	Looking up a definition in reading class; excited about our game
11:57 a.m.	Shooting free throws in gym
2:44 p.m.	Spelling in English class; excited because the game will be videotaped
9:10 p.m.	Happily talking with friends and eating pizza at a restaurant
9:05 a.m.	Talking to mom in the kitchen
10:58 a.m.	Playing catch outside with little brother; thinking about dad's friend
1:13 p.m.	Being forced to play football with my brother
2:20 p.m.	Playing football in the backyard
3:42 p.m.	Watching Notre Dame fumble in its game with Penn State on TV
6:12 p.m.	Drowsily babysitting and making hotdogs
6:45 p.m.	Running a bath for my little brother
8:09 p.m.	Watching "Witness" on VCR while tired
10:53 a.m.	Watching the morning pregame show (Dallas versus San Diego)
11:39 a.m.	Watching the game between the Patriots and the Rams
2:42 p.m.	Watching a Bears' game with dad
7:24 p.m.	Staring at my drink in the kitchen after a hard workout
8:37 p.m.	Babysitting at a friend's house
10:11 a.m.	Watching a film on Johnny Appleseed in the library
12:28 p.m.	Thinking in social studies class about the girl I like
6:23 p.m.	Looking for my brother; thinking about his driver's training
7:15 p.m.	Bored while talking to confirmation class instructor
9:24 p.m.	Reading *Sounder* in the living room for a book report
8:44 a.m.	Taking a quiz on nouns; excited because we get to skip our last class
11:17 a.m.	Solving a problem in math class
12:01 p.m.	Shooting free throws in the gym (I was 3 for 3.)
6:11 p.m.	Watching eighth-grade team getting beaten at another high school
8:01 p.m.	Helping mom make her bed
9:25 p.m.	Doing homework for social studies in my bedroom
8:25 a.m.	Studying for confirmation class while sick at home
11:15 a.m.	Getting up to answer the phone while watching videos
1:12 p.m.	Reading the Bible with mom in the bedroom
5:00 p.m.	Playing football and watching "Different Strokes" in TV room
5:56 p.m.	Saying prayers before dinner and discussing being a priest

Social Context

Figure 2. **Frequency of Emotional States of Adolescents in Social Contexts**





states occur more regularly in the contexts of school, friends, and family.

School. Selman is somewhat unusual in the amount of enjoyment he experiences in his classes. When in class, most teenagers on the average report lower moods and high rates of frustration and tension. Figure 2 shows how frequently a sample of about 300 seventh, eighth, and ninth graders reported different types of feelings in class and in other social contexts. School is the workplace of adolescents, and their work is generally harder, more alien, and more closely monitored than most of the work adults experience in their jobs. Few of us are asked to master a new area of learning every week, and few of us are subject to such constant evaluation and criticism. Especially for students who do less well academically, school is typically a context of daily stress.

Friends. The antidote for the pressure of school is friends. Consistently, we find that the best times in teenagers' lives are occasions with their friends. Selman, for example, reports he experienced many of his best moods when riding home on the bus, shooting freethrows, and eating pizza with his pals. When he is with his friends, many of his other concerns slip away, and he becomes completely absorbed in their activities and discussions. Our interviews suggest that teenagers are experts at having fun with each other; they know what to do and what to say to create a situation of fluid, pleasurable interchange. They often experience states of deep enjoyment — a depth of enjoyment that adults rarely encounter — in which the pressures of school, hassles with parents, and the neglect of youth in an adult-oriented society cease to exist. Unfortunately, in extreme cases, the value of prudence, the purpose of traffic laws, or the consequences of sexual activity may also be forgotten.

Family. Being with the family is much less fun but can provide an important counterweight to the emotional power of friends. On the average, the moods of adolescents when with the family are in the neutral range. They go to neither the positive nor the negative extreme. Part of the reason is that activities carried out with the family are more likely to involve practical maintenance, like eating and doing housework. Unlike the requirements of being with friends, the requirements of family life regularly confront adolescents with mundane realities: someone has to take out the garbage, someone has to take care of one's 4-year-old brother, someone has to do without a second piece of strawberry cake. While less enjoyable, these realities present sobering lessons that may be an important part of adolescents' development. Ultimately one must learn to find enjoyment within the confines of such realities. Teenagers also report feeling more calm and less frustrated and nervous when with the family than in any other social context. For teens who are not at war with their parents, the home is an important refuge for relaxation and a respite.

Time alone. Time spent alone might be thought of as the fourth basic social or, in this case, asocial context of adolescent experience. This is quite often a time when teens experience their lowest moods and frequently feel lonely. My research has shown, however, that time spent alone is an important part of the full round of teenagers' daily lives. Adolescents go off to their bedrooms when there is nothing else happening in order to listen to music, lie on their beds, do homework, or do artwork. Afterward, they tend to feel more alert and cheerful. I have found that adolescents in high school who are never alone and those who are alone too often do more poorly in school and appear to be less well adjusted. This discovery suggests that an intermediate amount of time in this less happy context may, like a bitter-tasting medicine, play a constructive role in adolescents' mental health. Parents need to step back and give teenagers the option to have their privacy when they want it.

The contexts of class, friends, family, and time alone, then, provide four quite different types of experiences. In a teenager's ordinary day, these experiences follow each other in rapid succession, creating a cavalcade of contrasting encounters; the adolescent experiences quick oscillations between states of tension, stress, enthrallment, and repose. Ordinarily these contrasting experiences complement each other: each one compensates for some of what the others lack. But for adolescents who are doing poorly in school or have a troubled home, few friends, or no opportunity for genuine solitude, this complementary quality may be absent, and like trapeze artists who miss a catch, they experience a free fall in open space.

Reed W. Larson, assistant professor of family ecology, School of Human Resources and Family Studies

Child Support Payments: Laws Are Not Enough

Andrea H. Beller

U.S. families are undergoing a major transition: they are changing in form from predominantly two-parent to single-parent families, usually headed by a woman. Female-headed, single-parent families comprise 19 percent of all families with children under 18, an increase of 9 percentage points since 1970. This growth in female-headed families comes from increases in the divorce rate and in the number of children born out of wedlock. If recent trends continue, nearly 6 out of every 10 children born in 1985 will spend some time in a single-parent family. Such families usually exist at relatively low levels of economic well-being and make up a disproportionately large share of the population living in poverty. An important means of providing for their economic well-being is child support payments.

Less than half receive payments. Many absent fathers do not contribute to the support of their children, leaving this task instead to the woman or to the state in the form of welfare payments. According to a Census Bureau survey of the U.S. population, in 1979, only 59 percent of mothers with children from an absent father had a child support award as Figure 1 illustrates. Among those with an award and due payment, only about half received full payment. About a fourth received partial payment, and a fourth received no payment at all. The average amount of annual child support received was only $1,800 for close to two children. As low as this was, recent statistics show that the real value of child support received declined between 1983 and 1985. My research is designed to assess the reasons for this decline.

The passage of Title IV-D of the Social Security Act in 1975 required each state to develop a child support enforcement program to assist in establishing paternity, locating absent parents, establishing obligations for child support, and enforcing such obligations. In 1984, the federal Child Support Enforcement Amendments strengthened the nation's system for enforcing child support by requiring all states to:

- withhold wages automatically when support payments are overdue.
- use administrative procedures and other expedited legal processes for obtaining and enforcing support orders.
- provide for the collection of overdue support by intercepting state income tax refunds.
- initiate a process for imposing liens against real and personal property.
- maintain procedures for requiring security, bond, or other guarantee of payment.

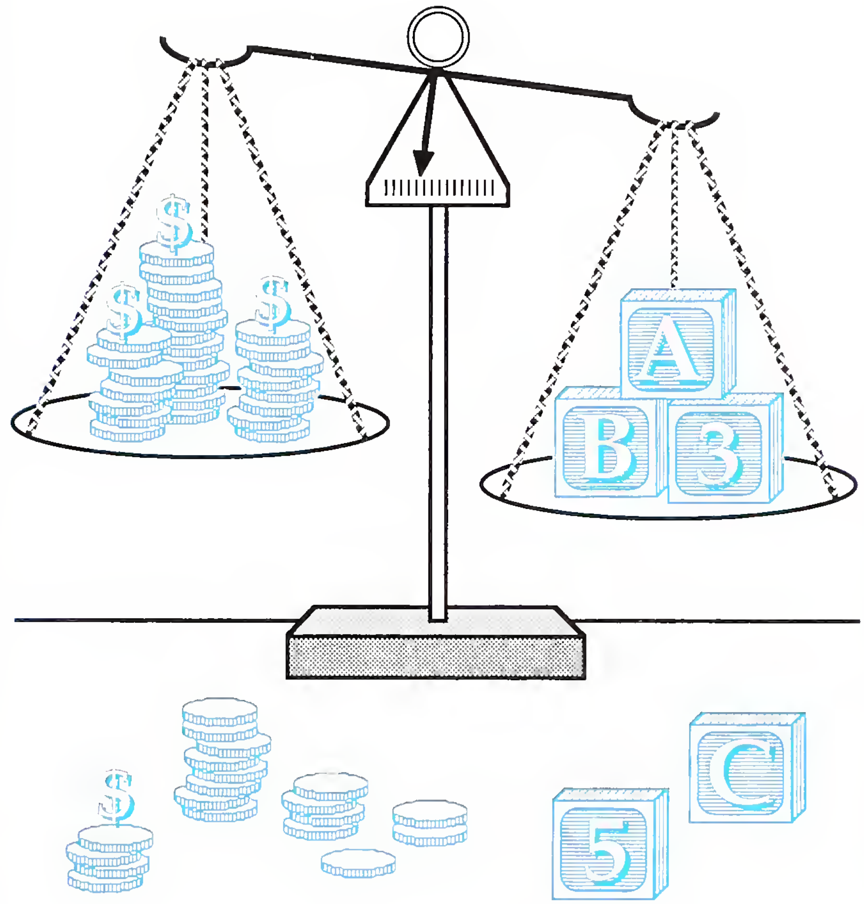
Laws are no guarantee. One way to determine how effective these new laws probably will be is to examine the effect of similar laws already on the books. In a study of 1981 state laws, I found that liens and administrative procedures were effective at increasing child support receipts. Laws for the mandatory withholding of wages that were in effect for at least 3 years were also effective, but only moderately so. I have concluded that federal officials

need to realize that the passage of state laws alone does not guarantee their effective enforcement. Although these amendments are promising, on the basis of past experience I am not optimistic that they will revolutionize child support in America.

The inevitable conclusion is that only a complete overhaul of the present child support system could substantially reduce the economic insecurity facing many female-headed, single-parent families. Short of that, we must proceed on a number of fronts. We must continue our efforts to increase women's earnings, to help women make the transition from working in the home to working for pay in the market, and to implement a better system of good child care at affordable prices.

Andrea H. Beller, associate professor of family economics, School of Human Resources and Family Studies

Unfortunately, many absent fathers are not paying for a fair share of their children's needs as legislated by the courts; therefore, many of these children live in poverty.



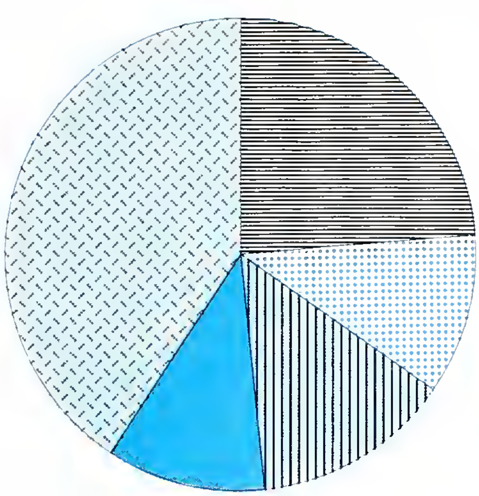


Figure 1. **Child Support Payments to All Mothers with Children from an Absent Father, 1979**

- Supposed to receive and received full payment
- Supposed to receive and received partial payment
- Supposed to receive but did not receive payment
- Awarded but not to receive payment
- Not awarded support

Social Relationships Ease Stressful Transitions

Robert Hughes, Jr., Elaine S. Good, and Kristin Candell

> *"The most powerful factor in relationships, we found, is the degree of reciprocity..."*

Understanding how people cope with stressful situations has been the focus of much study in the last several decades. As people face difficult transitions, such as the birth of a child, the disruption of their marriage, or the death of a close family member, researchers have found that people often experience serious psychological distress and have difficulties making adjustments to their new situation.

A major source of help in coping with these transitions is the informal support provided by family, friends, and neighbors. This informal help, called social support, can range from practical aid, such as helping with household chores, to emotional support. Researchers studying a wide range of personal difficulties have found that social support can often help ease the strain and stress of difficult experiences.

Is support always helpful? Initially, research seemed to indicate that simply having more people around providing different types of help was beneficial, but recently the evidence has become more contradictory. Studies by Karen Rook at the University of California at Irvine found that having support was not particularly helpful, but not having it was harmful. John Eckenrode and his colleagues at Cornell University have found that some people benefit from support, whereas others either do not benefit or are harmed by the aid of family and friends. Although this more recent evidence questions the earlier research that indicated unlimited benefits from help through social ties, it still suggests that social relationships can exert a powerful influence on our ability to cope and on our sense of well-being.

Research on separation and divorce. At the University of Illinois at Urbana-Champaign, we are trying to untangle these puzzling findings. In our search to understand where, when, and how social ties affect well-being, we have assumed that social relationships can have both positive and negative effects on the psychological well-being of individuals and have focused our study on women who have recently been separated or divorced. Marital disruption is a very stressful life transition that can have profound effects on an individual's well-being. Our primary interest has been to understand how social support changes over time and how it affects the well-being of these women. We hypothesized that adjusting to this significant change in their lives would require that they establish supportive relationships and that this task might necessitate the formation of new relationships or the transformation of existing ties.

We have tried to identify which aspects of those new or transformed relationships were helpful by conducting three interviews: the first within 2 or 3 months of filing for divorce or the granting of the divorce, another interview about 3 months later, and a final interview about 4 months after the second interview. In each interview, we asked the women to identify those persons who provided them with practical support, material support, information, opportunities for socializing, feedback, and intimate support. We also asked them to provide some demographic characteristics of these people, such as the age of their children and their marital status, how they were connected with others in their network, and the degree of closeness and conflict the study participant felt toward these individuals.

Diverse social ties. Our initial results indicated that these separated and divorced women had very diverse social ties. They reported having on the average about 15 network members, the smallest reported network containing only 3 individuals and the largest, 37. Some networks were composed mostly of kin; others included mostly friends. For most of the women about two-thirds of their network was composed of friends, and the remainder was kin. We hypothesized that separated women would have different networks than divorced women, but no systematic differences were evident in this sample.

Changing composition. As expected, the networks of these women changed over time. Initially, they indicated that, on the average, they no longer had contact with about 4 people who were a part of their networks before the separation. Most of these initial dropouts were friends and in-laws. Between the first and second interviews, they added about 5 new relationships, but also lost another 4 ties. Most of the lost relationships were terminated because both parties decided not to continue remaining friends. Between the second and third interviews, the women added about 5 new relationships and again dissolved about 3 ties with others. Thus, in about a year, these women established and discontinued many relationships.

Lost social support found harmful. The next stage in our analysis was to determine whether the changing relationships improved well-being. Preliminary results seem to indicate that the loss of social ties has an adverse effect on mental health and that the establishment of new relationships has a beneficial effect. But this was not the case for dissolved relationships the women had before the separation. Women who dissolved relationships held before the separation were less likely to suffer

The quality of relationships in a network influences the well-being of its members, not the mere fact of its size or density.

from obsessiveness, have interpersonal problems, or be depressed.

Perhaps the most important question, however, is what in these relationships contributes to well-being. Some theorists have argued that close-knit networks, in which most of the people know each other, are more helpful than loose-knit networks. Our findings suggest that the degree of connectedness has little relationship to well-being. They also indicate that the size of network alone has little impact; therefore, large and small networks may be equally beneficial.

We expected that feeling close to members of the network and not having much conflict would be related to well-being. We found that feeling close is related to well-being, but we did not find any effects due to conflict.

Reciprocity promotes well-being. The most powerful factor in relationships, we found, is the degree of reciprocity, that is, the extent to which the support in a person's network is mutually given or given more to oneself or to the other person. Mutual relationships promoted better mental health, whereas one-sided relationships produced more distress.

Different kinds of support needed. We examined the types of assistance that seemed most helpful and found that there were differences in the kinds of support needed by separated and divorced women. For separated women, practical help, socializing, and feedback were related to good mental health; for divorced women, only material support promoted positive well-being. These results suggest that support is generally more beneficial to separated women. Also, they confirm that different types of help are needed by people at different times in their lives. Support will be beneficial only if it is needed at a particular time.

"For separated women, practical help, socializing, and feedback were related to good mental health; for divorced women, only material support promoted positive well-being."

Implications. In general, these findings suggest that although social ties can be helpful, it is a complex relationship. It is not safe to assume that more social support will always improve well-being. As we think about strategies for helping people cope with transitions in life, we need to identify the specific kinds of support that are helpful and the most beneficial times for giving it. For single mothers like those in this study, it appears that practical help, invitations to social activities, and feedback about decisions are most useful during separation. Material assistance, such as financial help, appears to most influence the well-being of already divorced mothers.

These results also indicate that the quality of social relationships affects well-being. Women who were able to establish and maintain ties that involved the mutual give-and-take of support had better mental health than those who were more often on the receiving end of help. Those giving help should remember to provide others with opportunities for giving help in return. Maintaining reciprocal relationships in the long run may be essential to each other's well-being.

Although the actual size and density of the network had little effect on well-being, changes in the network had a substantial impact. We should not be concerned, therefore, with the size of a network, but with whether it is getting larger or smaller over time. Increases in a network lead to improved well-being; decreases lead to more problems. We should encourage women who are becoming increasingly isolated to participate in support groups and other social activities that may lead to new friendships.

There are still many questions about how social relationships help people cope with stressful transitions in life. But research on the kinds of help that will be most beneficial and on the critical times for giving help will improve our ability to lessen the distress of others.

Robert Hughes, Jr., associate professor of family relationships and Extension specialist, Elaine S. Good, visiting research associate, and Kristin Candell, research assistant, all of the Division of Human Development and Family Ecology, School of Human Resources and Family Studies

Family Financial Management Leads to a Better Quality of Life

Vicki Schram Fitzsimmons and Jeanne L. Hafstrom

Three major economic events have had dramatic effects on the quality of life in the United States. High ratios of debt to income have contributed to the financial and emotional crises of many farm families. The October stock market crash wiped out income reserves and income sources for large numbers of young urban professionals, leaving them out of work and emotionally distressed. Lottery winnings have given windfall income to "average" families and individuals, allowing them to achieve higher levels of financial security than they dreamed possible. These events illustrate the negative and positive results when risk taking becomes the major tool for financial management.

Management makes the difference. Financial management is the way people make decisions about spending and saving. Good managers are able to spend effectively to get what they want for the best price. They also save for emergencies and other goals. They take financial risks suitable for their level of income and the stage of their family's life cycle. In times of uncertainty, good managers cope well because of accumulated reserves and management expertise. Because families manage finances and other resources differently, we surmise management determines which families will "make it" and which will not.

Current research should help to identify how resource utilization contributes to differences in the economic well-being and quality of life of Illinois and other rural families. Results will provide information for Extension programs and community planning and will be used to assist families in managing resources more effectively.

Perceptions influence levels of satisfaction. A related question is why families with the same level of income and similar family characteristics have different satisfaction levels with their quality of life. In a recent study of Illinois and Indiana families, Vicki Schram and Marilyn Dunsing found that perceptions of past, present, and future financial situations are as important as income in determining satisfaction with one's quality of life. Jeanne Hafstrom found that wives in metropolitan areas were relatively more satisfied with their quality of life than were their nonmetropolitan counterparts. In her study, satisfaction with the amount of family consumption was most important to midwestern families in assessing their quality of life. In both projects, subjective indicators were more important than objective measures in explaining reactions. Therefore, families with the same basic level of income and similar family characteristics seem to have different levels of satisfaction because they perceive their financial situations differently.

Vicki Schram Fitzsimmons, assistant professor of consumer economics, and Jeanne L. Hafstrom, associate professor and chair of the Division of Family and Consumer Economics, both of the School of Human Resources and Family Studies

Clothing: Our Portable Protection and Adornment

Mastura Raheel, Hilda M. Buckley, and Karen K. Leonas

Three commonly noted purposes for dressing the body are adornment, modesty, and protection or utility. Adornment historically has been the overriding factor, and modesty, the result rather than the reason for wearing clothes. Protection and utility, however, are gaining importance as the complexities of modern life become more challenging.

Protective value of clothing. The comfort and optimum functioning of the human body depend on how it interacts with its physical environment. The potential protective and regulatory characteristics of clothing are important because clothing is our closest environment. As a portable environment, clothing has a broader meaning than it has traditionally been given and encompasses products from helmets and boots to specialized athletic gear, as well as environments from space suits to isolation chambers. Protective clothing is necessary for fire fighters, scuba divers, and those who work with steel, glass, electronics, pharmaceuticals, and pesticides and other toxic chemicals.

Dermal exposure to pesticides. Much concern has been expressed about the effects of the 2.7 billion pounds of agricultural chemicals used each year to control insects, weeds, and fungi on crops and lawns in the United States. Exposure to pesticides continues to be a problem for agricultural and urban workers who mix and apply them. Homer Wolfe, Howard Maibach, and others have shown that the absorption of pesticides through the skin accounts for 97 percent of the pesticide entering the human body, yet pesticide users are not as aware of dermal exposure as they are of inhalation exposure.

Properly designed protective clothing can provide a physical barrier that reduces chemical contact with the skin. Herbert Nigg and others have shown that it reduces dermal exposure as much as 65 percent for applicators and 40 percent for mixer loaders. Impermeable protective clothing is commercially available; however, it is generally not acceptable to users. As a result, agricultural and urban pesticide applicators continue to wear conventional work clothing. Additional protection can be achieved through the use of head coverings, impermeable boots, and gloves. Wearing gloves as protective apparel might become more widespread if individuals would recognize, as Maibach and his co-workers have reported, that scrubbing the hands one minute after exposure only removes 25 to 35 percent of the pesticide residue and that more hand washing has little or no effect.

Dermal exposure can also be reduced appreciably by proper laundering procedures, which remove pesticides and allow clothing to be safely reused. Our research has focused on the barrier properties of commonly used textiles toward pesticide penetration and on refurbishing variables that affect the retention and release of pesticide residues.

Specifically, we have studied:

- how pesticide solutions penetrate and move through the fabric.
- the resistance of commonly used textiles to degradation from exposure to pesticides.
- the structure of fabrics that influence pesticide penetration and retention.
- the effects of the type of fiber and functional finishes, such as durable-press and fluorochemicals, on the barrier properties of textiles.
- appropriate decontamination methods for garments exposed to various insecticides and herbicides.
- discoloration of work clothing and carpet dyes due to pesticides.

Barrier properties of fabrics. We have studied several conventional fabrics and compared their effectiveness as a barrier with spunbonded olefin fabric (Tyvek), which is an excellent barrier against pesticide penetration and is commonly used for disposable protective coveralls. We contaminated the fabrics with insecticides and herbicides and analyzed the amount of pesticide transmitted through them on an absorbant surface, using gas chromatography.

Textiles included in these studies were structurally similar woven fabrics of cotton, polyester-cotton blends (65/35 and 50/50), nylon, polyester, and acrylic. One set of fabrics was left

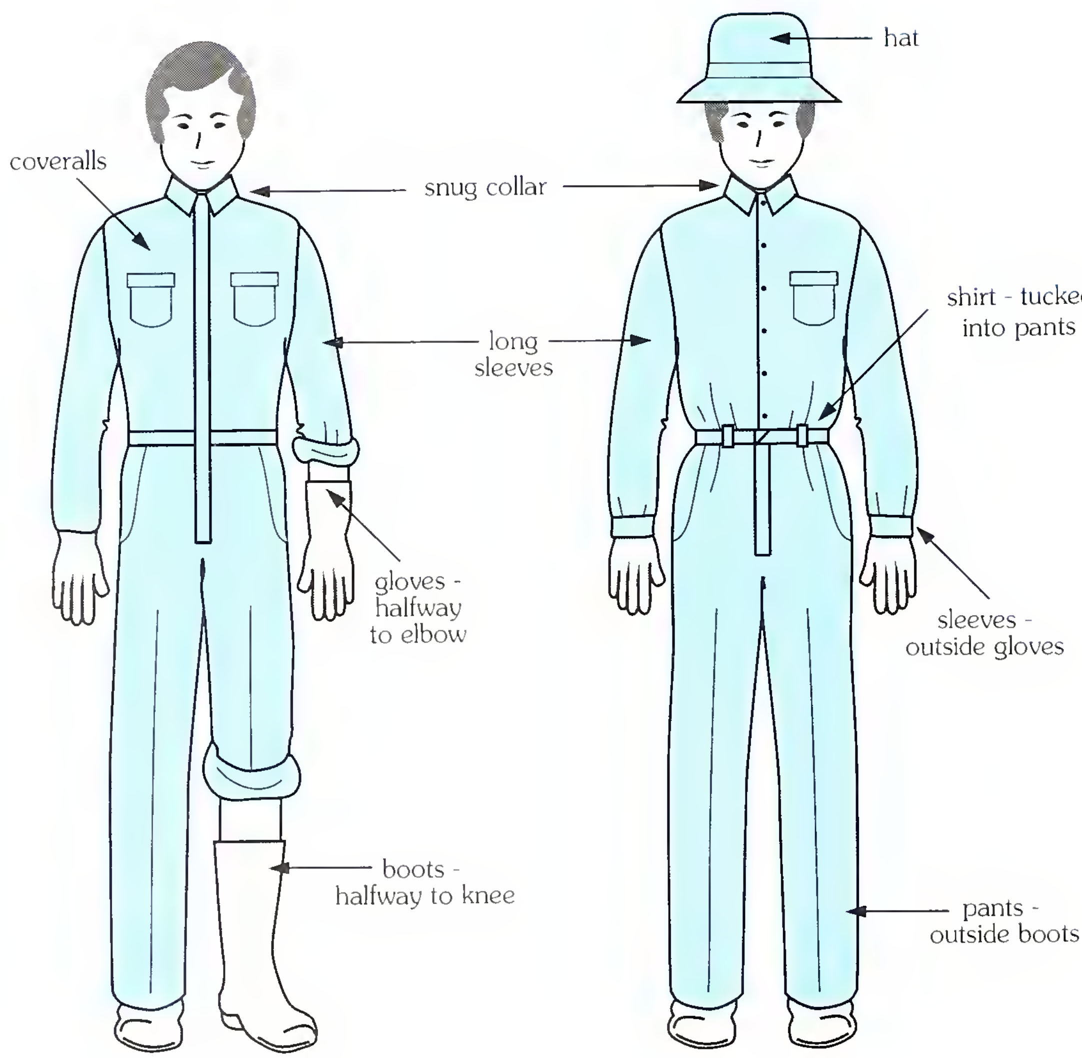
"...the absorption of pesticides through the skin accounts for 97 percent of the pesticide entering the human body, yet pesticide users are not as aware of dermal exposure as they are of inhalation exposure."

unfinished, while the other sets were treated with durable-press and fluorochemical (Scotchguard-type) finishes.

Textiles are complex structures relying on the components of fibers, yarns, fabric structure, and finishes. It is, therefore, difficult to isolate a specific property that is solely responsible for their overall effectiveness as a barrier. But, by measuring an individual fabric property and comparing it with the amount of pesticide transmitted, it is clear that some properties influence pesticide transmission more than others. We found that fiber type influences pesticide penetration and that cotton and polyester-cotton blend fabrics are better barriers than nylon, polyester, and acrylic. We also found that as fabric thickness increased, less pesticide was transmitted. Furthermore, fabrics with loosely twisted yarns, such as twill fabric in this study, permitted less pesticide penetration than plain weave fabrics that have tightly twisted yarns. However, unfinished fabrics transmitted from 6 to 90 percent of the pesticide solution. But when cotton and polyester-cotton fabrics were treated with a fluorochemical finish, they became as effective barriers as the spunbonded olefin fabric. This finish should be reapplied after 2 to 3 launderings. The durable-press finish, however, did not appreciably improve the protective qualities of polyester-cotton fabrics.

Decontamination of fabrics. We examined the effects of water temperature, the type of detergent, pesticide formulation, fiber content, the structure of the fabric, and textile finishes on how easily and completely pesticide residue could be removed. Results indicated that hot- (140°F, 60°C) and warm-wash (120°F, 49°C) temperatures are equally effective in removing pesticides but that a cold-water wash (86°F, 30°C) is not. We also found that a heavy-duty liquid detergent (HDL) is most effective in removing the emulcifiable concentrate formulation of pesti-

Appropriate Clothing for Pesticide Applicators



Be sure to wear goggles and respirator while spraying pesticides.

cides, and that granular detergents are equally effective in removing wettable powder or liquid formulations. A HDL is also better for removing pesticides from durable-press and fluorochemical-finished fabrics. The type of fiber and the weight of the fabric do not significantly affect residue removal. One wash removed 98 percent or more of field-strength pesticide contamination. But, even 10 launderings did not remove full-strength pesticide contamination, which may result from spills during mixing and loading. We, therefore, recommend:

- impermeable coveralls, hats, gloves, boots, and other protective clothing as shown in the preceding figure.
- not wearing 100 percent synthetic fiber conventional garments when handling and applying pesticides.
- using repellent fluorochemical finishes on conventional work clothing when comfort and availability preclude the use of impermeable clothing, and reapplying these finishes after every second laundering.
- laundering clothing the day that it is contaminated.
- prerinsing and washing with warm or hot water rather than cold to decontaminate clothing.
- not wearing light weight fabrics when working with pesticides because of the potential for greater pesticide penetration even though pesticides are more efficiently removed from them.
- storing and washing contaminated clothing separately from other family clothing.

Aesthetic value of clothing. Although wearing clothing to protect oneself against exposure to pesticides is a logical solution to the problem, humans, by nature, will not wear clothing, no matter how much it protects them, unless it is personally and socially acceptable. In fact, historically and cross-culturally, people have worn items of dress that they consciously have known to be detrimental to their body's health and functioning. Anthropologists have found that personal adornment is a universal behavior. Why do humans put so much emphasis on the aesthetic value of clothing? We have found that the three main reasons are to build our level of self-esteem, to express messages nonverbally to others, and to facilitate interpersonal relationships.

Source of self-esteem. In a recently completed study, we have found that for most people dress is important because it can be a source of positive feelings: when people feel that they look good, they feel good about themselves. Dress also helps people act out the roles society decrees for them.

Means of nonverbal expression. In our fast-paced society, many social encounters are fleeting. As a result, we form impressions of others quickly, using the limited available cues from observable characteristics and behaviors. Because apparel is readily observable, easily manipulated, and believed to be a matter of personal choice, it often serves as an index of personal characteristics.

We have found that specific social and political attitudes, personality traits, and social status are symbolically transmitted by dress. We are currently studying how people structure their perceptions of apparel. Findings suggest that members of one sex judge clothing worn by the opposite sex on the basis of its structure or form, but they consider the context or situation when clothing is worn by members of their own sex. Such research serves to help people understand how and why the sexes react differently to dress and can, thereby, show how dress facilitates interpersonal relationships.

Filtering function in relationships. The assumptions made about others on the basis of their dress often stem from social stereotypes that may or may not be true about individuals. Nonetheless, these assumptions do facilitate setting the stage for future interaction. As a result of a number of experiments on interpersonal attraction, for instance, we have discovered that in first-impression situations, dress worn by two people of the same gender significantly affected the attraction between them. We found not only that dress perceived as similar stimulated more attraction than dissimilar dress, but also that there is a positive linear relationship between the degree of similarity in dress and attraction. Consequently, we can predict the level of attraction between individuals from a description of dress.

Our findings suggest that dress serves a filtering function during interactions. People decide who their acquaintances will be on the basis of dress. Such information contributes to our understanding of failures and successes in a variety of interpersonal relationships, including, for example, those involving dress codes or fleeting interactions with the public. These findings can help people decide upon appropriate apparel and can give them confidence in crucial first contacts.

What we choose to wear when we mix and apply pesticides is influenced by our knowledge of the barrier properties of fabrics and specific forms of clothing. This knowledge, however, is not enough. We must also be aware that people, as humans, need to dress in personally and socially acceptable ways, for clothing not only creates a physical environment within which our bodies function, but it also creates a visual environment within which we behave and interact with others.

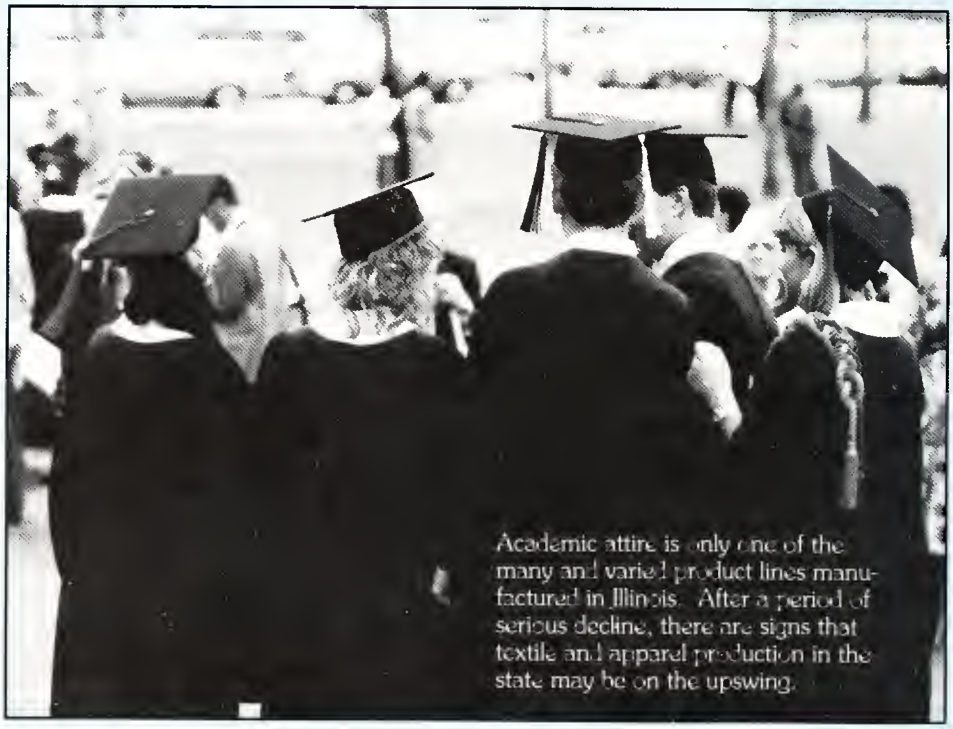
"...we can predict the level of attraction between individuals from a description of dress."

Mastura Raheel, associate professor and chair of the Division of Textiles, Apparel, and Interior Design, Hilda M. Buckley, associate professor of textiles and clothing, and Karen K. Leonas, assistant professor of textiles and apparel, all of the School of Human Resources and Family Studies.

The Future of Illinois's Invisible Textile and Apparel Industries

Sara U. Douglas

As alarm has mounted in the 1980s over the record levels of the textile and apparel trade deficit, serious attention has belatedly been focused on the problems of the industry. Although industry performance has improved in the past year, sustaining it will not be easy. A recent consumer survey has indicated that the textile and apparel industries also have a public image problem — not a negative image problem, but a nonimage problem.



Academic attire is only one of the many and varied product lines manufactured in Illinois. After a period of serious decline, there are signs that textile and apparel production in the state may be on the upswing.

Growth expected. Illinois is one of many states where the failure of a number of small textile and apparel businesses and the consequent unemployment during the last 6 years have had a noticeable effect on the state's economy. Continued erosion would undermine the industrial base of the state and add significantly to economic distress and related social problems. These Illinois industries, however, will probably be able to improve and expand, aided by a decentralizing marketing system, communication technology, and the popularity of regional merchandise marts in Chicago. Moreover, young avant-garde designers in Illinois are receiving increasing national attention and transforming Illinois's reputation for conservative, rather dull textile and apparel products.

A questionnaire mailed to the presidents of textile and apparel manufacturing firms in Illinois has revealed that few firms have more than 500 employees and that most firms are small, privately owned companies that employ primarily semiskilled workers. Over half of the textile companies produce industrial textiles. Most of the apparel companies produce either women's apparel, men's or women's uniforms, or work clothes.

Opportunities not found in technological changes. About half of the firms in each industry reported that no technological improvements had been added to their manufacturing facilities in the past 2 years. Those in the apparel industry viewed this as a major problem, yet respondents in neither industry saw technological change as a major opportunity for their companies' future growth. In textiles, these opportunities were seen in expanding domestic markets and increasing productivity and efficiency. The problems these textile companies perceived to be significant involved government policies and actions, and the availability and costs of raw materials. In apparel, respondents considered increased productivity and efficiency to be the most important opportunities for growth, and they thought that expensive technology and foreign competition were the major problems. Few of the Illinois companies engage in international activities.

Steps to increase visibility. This descriptive profile of the industry explains its nonimage. Yet, respondents in both industries strongly agreed that their companies are placing more emphasis on the quality of their products, productivity, short-run production, flexible production schedules, and customer service than they did 2 years ago. Most are also strongly supportive of the inter-industry effort to publicize U.S.-made products. Almost half of the respondents in both industries replied that they are also doing more marketing and advertising than they did 2 years ago. These efforts should not only help improve the visibility of the industry for consumers, but, more importantly, they should also improve its competitive position and allow for future growth.

Sara U. Douglas, assistant professor of textile and apparel marketing, School of Human Resources and Family Studies

The Home: Shaping Our Environment

Joseph L. Wysocki

The challenge of the 21st century is to shape our environment to fit our human needs rather than let it shape us.
Illustration from a J.C. Penney filmstrip, *Your Space or Mine?*

Shelter or housing is one of the most basic human needs. More than a roof over our heads, a surface that merely covers or gives protection from the elements, a home must also provide an atmosphere that is conducive to a better way of life. The health and viability of this nation depend on the quality of the family's private envelope — its dwelling.

The home, the hub of the family's private world, is where the family sheds the stresses of the modern world. Buffers between individuals and society, our homes are the last bastion of privacy, where we can express our individuality. Homes are also important because they are the part of our environment over which we have the most control. Winston Churchill is credited with having said, "We shape our buildings, and our buildings will shape us." Homes are manifestations of private property, family centrism, and other important cultural values. The impact that housing — the structure of our homes — has on individuals and families is immeasurable.

Economic impact. Economically, housing represents the largest financial commitment that many people make during their lifetime. A major portion of the household income goes for housing and housing-related expenses: debt retirement or rent, utilities, taxes, maintenance and repairs, insurance, and furnishings. As a result of changes in housing prices, interest rates, and energy costs, households are spending about one-third of their income for housing.

Housing is one of the most important factors in the well-being of families. In addition to its social and economic value, the home can directly affect a family's psychological health because individuals typically spend more than a third of the day in the home.

Socio-psychological impact. A family's psychological health can, in part, be a direct and indirect function of its housing. In a direct sense, a lack of privacy can adversely affect psychological well-being. Indirectly, economic resources spent to obtain good housing may have a negative psychological impact. For instance, a decision to spend an increased portion of family income for housing — perhaps because of rising energy costs — can create psychological stress.

Physiological impact. In a physical sense, housing is a dominant aspect of the human environment and therefore greatly influences health and well-being. Physiological well-being can be affected by housing decisions. What are the consequences for human health emanating from attempts to increase the energy-efficiency of housing, the installation of unvented space heaters, and the use of wood, kerosene, and other energy-saving and money-saving fuels? It is likely that some houses are so tightly caulked, insulated, and otherwise "tightened up" that potentially dangerous substances pollute the air. These attempts to save money with new devices and fuels for space heating have posed health threats.

Housing in the North Central Region. Housing researchers in the North Central states, supported by their respective agricultural experiment stations, are currently looking at many of these dimensions of housing. Five hundred rural families in Illinois, Iowa, Minnesota, Missouri, Nebraska, and Wisconsin were recently interviewed in this regional study to analyze the economic, social, psychological, and health consequences of their housing decisions. Under investigation were their decisions related to financing, energy use and conservation, type and location of housing, and remodeling or retrofitting of the dwelling. Data from this study will also provide valuable information about the housing conditions of North Central rural families.

The North Central Region is appropriate for such a study because it is characterized by severe and humid summers as well as cold, generally dry, winters. Energy costs to heat and cool houses and to respond to the variation in humidity are high in this region. The need to save fuel because of cost or scarcity can have additional negative

"It is likely that some houses are so tightly caulked, insulated, and otherwise 'tightened up' that potentially dangerous substances pollute the air."

unanticipated social, psychological, or economic consequences.

Rural areas are being addressed in this study because of pressures from the "rural renaissance" produced by urban-to-rural migration, first noted in the mid-1970s. In addition, the relative lack of regulation of housing in rural areas makes experimentation in energy-saving and money-saving devices more likely. For example, many cities ban the use of kerosene space heaters, whereas few rural areas do. The consequences of the relative lack of housing policies, financial institutions devoted to housing, and housing regulations should be studied.

Housing and energy. Researchers at the University of Illinois have been focusing on the decisions of rural people to use various types of heating and cooling systems in the home and to make alterations that improve its energy efficiency. These data were then compared to learn if there is a relationship between behavior regarding energy usage in the home and the well-being of a household.

Over 60 percent of the households surveyed use natural gas (46.6 percent) or liquefied petroleum gas (lp gas) for heat. Wood was used by 16 percent, electricity by 11, and oil by 10. The remaining households used coal or kerosene for heat.

Preliminary results indicated that 41 percent of the rural households in the North Central Region changed the energy efficiency of their homes within the last 5 years. Some of the major changes the households made included adding caulking or weatherstripping, ceiling or attic insulation, storm windows, wall insulation, and shade trees. As the accompanying bar chart illustrates, fewer homes added solar units or windbreaks, such as fences.

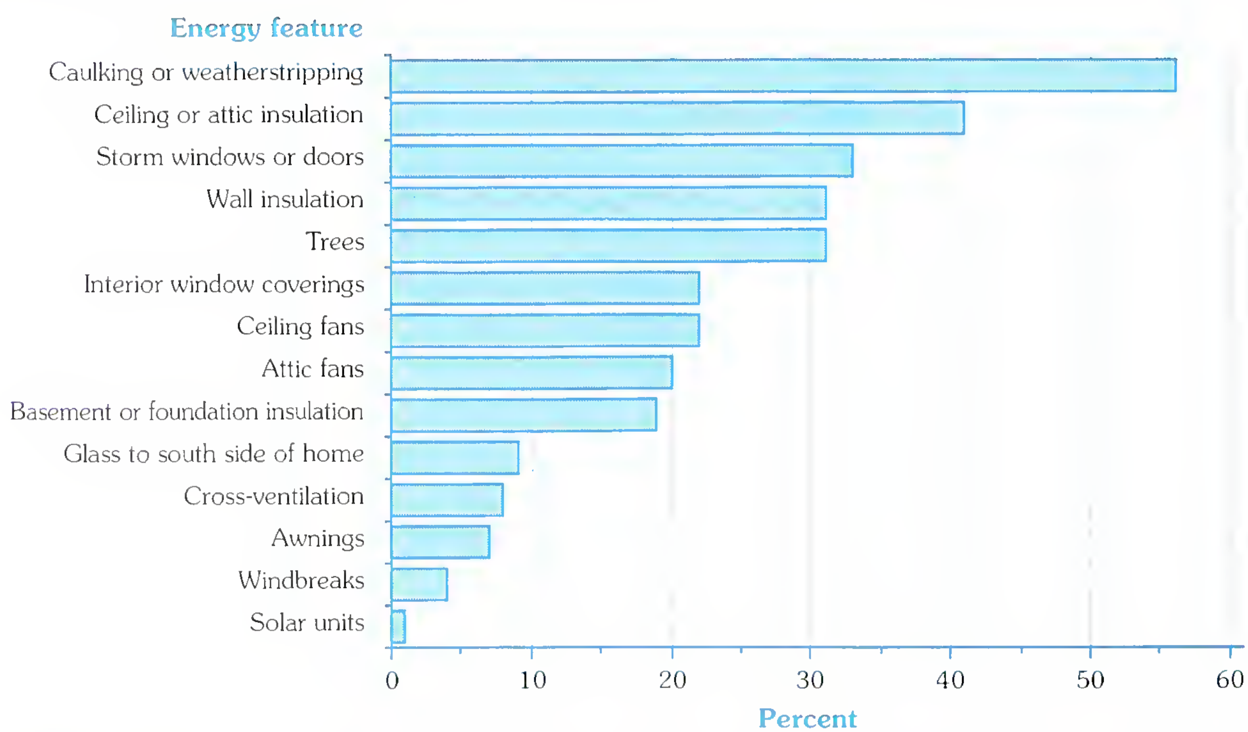
How have these energy improvements affected the well-being of these households? Generally, the households that improved their energy efficiency represented higher levels of satisfaction or well-being as compared to those that did not make these improvements, especially with regard to the economic, physical, and psychological well-being of the family.

Implications. This research will be useful to many people in decision-making capacities: Extension advisers in program planning and in helping clients evaluate alternatives in housing decisions, officers of lending institutions in evaluating their policies on creative financing, community planning groups in making decisions and developing policies that influence commuters, builders in identifying potential markets for different housing types and structures in relation to urban or rural location, and policymakers in energy agencies and utility companies in assessing the consequences of energy decisions. These examples show the potential for adjustments in housing-related policies and decisions that can increase the well-being of families.

The real challenge and message from the research concern the impact that housing has on its occupants. Do we allow ourselves to be shaped to fit our human environment, or do we shape our environment to fit our many human needs? Housing in 50 years should not look like it does today. This research will help us make important housing decisions to meet the needs of all people and add to their satisfaction and well-being.

Joseph L. Wysocki, assistant professor and Extension housing specialist, School of Human Resources and Family Studies

Percent of North Central Regional Rural Households That Made Various Energy Improvements



The Many Functions of Turfgrass

Thomas Voigt and *Thomas Fermanian*

Throughout history, from early references about lawns in medieval towns and cities to today's high-quality putting greens, turfgrass has been an important component of the human environment. During the 16th and 17th centuries, many North European towns and villages had a "green" or "common" of grass or turf. These areas were used as parks and sports facilities, as well as functional areas for grazing livestock. Although livestock grazing in city parks is no longer a common practice, over 5 million acres of turfgrass perform numerous other practical and aesthetic functions in our national landscape.

We now see and use turfgrass in a variety of settings. Small plots or lawns provide beauty and recreation for families and other small groups. Larger turf areas, such as parks or recreation areas, serve us as places for peaceful meditation, picnics, children's play, and athletics. The large turfed areas of the more than 13,000 U.S. golf courses attract millions of avid golfers annually. The National Park System has over 14,000 acres of mowed turf in nearly 600 areas. Industrial lawns, school grounds, cemeteries, campgrounds, and shopping centers use turf for controlling erosion, reducing dust, and beautification. Huge acreages of turfgrass serve these same purposes along roads and interstate highways, airport runways, railroad and utility rights-of-way, race tracks, and military areas. For example, much of our 42,000 miles of interstate expressways is bordered by mowed turf. It is easy to take this huge amount of turf for granted even though it adds immeasurably to our everyday life.

With the large selection of available ground covers, including turfgrasses, other plants, and man-made materials, why are turfgrasses preferred in so many settings? Although millions of dollars are spent annually on the upkeep of turf, initially, it is inexpensive. One thousand square feet of Kentucky bluegrass turf will cost less than $30 for seed and fertilizer. The same area planted to a ground cover, such as English ivy, spaced on one-foot centers or finished with a man-made covering, like a 4-inch thick pad of concrete, can easily cost from $300 to $600 for materials alone. Visually and practically turfgrasses have much usefulness. Besides initially being a real bargain, turfgrass is more versatile than any other surfacing material.

Controls erosion and improves soil conditions. Turfgrasses control wind and water erosion and improve conditions in the soil. The grass blades slow wind and water movement, while the shallow, fibrous roots hold the soil in place and protect the soil. Erosion can occur where there are bare areas as small as 2 inches in diameter. Because turf provides a dense cover, small, erodible areas generally do not exist. Turf improves the growing conditions in the soil by adding organic matter to it as old roots die and are replaced by new ones. Turfgrasses also reduce water runoff and evaporation from the soil, thus improving the availability of moisture from irrigation or precipitation.

Reduces pollution. Turfgrasses help reduce gaseous, particulate, and noise pollution. Carbon dioxide gas is absorbed and used by plants during photosynthesis. This process not only removes carbon dioxide from the environment, but it also replaces carbon dioxide with oxygen, diluting other gaseous pollutants. It is estimated that 2,500 square feet of turf provide the daily oxygen requirements of a family of four. Turf is also responsible for capturing much of the estimated 12 million tons of dust and dirt released into the environment yearly. Many of us are concerned about noise pollution. Turfgrass leaves perform a great service by absorbing noise. They have reduced noise by 8 to 10 decibels when used on either embankment near a depressed expressway.

Modifies climate. On a sunny summer day temperatures immediately above turfgrass can be from 10° to 14°F (about 5.5° to 7.7°C) cooler than above bare soil and up to 30°F (about 16.6°C) cooler than the temperature immediately above an asphalt or concrete surface. An average front yard has the amazing cooling effect of 8.7 tons of air conditioning (more than 100,000 Btu per hour)! The average home's central air conditioner has a capacity of 3 to 4 tons (36,000 to 48,000 Btu per hour). Furthermore, through evapotranspiration, actively growing turf and its underlying soil can change the humidity by adding more than 125 gallons of water per 1,000 square feet to our atmosphere on a warm, windy day.

Tolerates traffic and permits safer play. Turfgrasses tolerate traffic much better than most other low-growing plants. They also are a safer playing surface. Well-maintained natural turf fields can provide the firm footing athletes need but are much more forgiving than their artificial counter

part. The severity and number of many injuries that occur on artificial turf or poor-quality natural turf could be reduced if a high-quality natural turf were in place. High-quality natural turf has a degree of resiliency or cushioning that is safer for athletes in contact sports as well as for athletes in noncontact sports, children in play areas, and joggers.

Increases the value of property. Property values and the attraction of commercial properties can be partially tied to the quality of turf. An open, off-colored, or weedy turf makes property less appealing and reduces the effectiveness of signs or architecture in commercial properties.

Along with the difficulty of the golf course's layout, the quality of its turf can be an important factor in the amount that can be charged for a round of golf. A challenging layout with high-quality turf can command fees in excess of $80 for a single round. In general, high-quality turf is more valuable than poor turf.

Enhances the beauty of a landscape. Although there are numerous practical reasons for using turfgrass, most of us select it for its visual appearance. As the floor of the landscape, turfgrasses have a pleasant, inviting look. They can unify or tie other ornamental plants and manmade structures into a cohesive landscape picture.

During the 17th and 18th centuries, large houses featured expanses of lawn. This landscaping practice has persisted, and today is *de rigueur*. Most modern landscapes feature a turfed front yard. Landscapes for homes without it are considered avant-garde or different from the norm.

Several components — texture, density, color, smoothness, growth habit, and uniformity — combine to create the visual appearance of turf. We perceive a finer-textured turf, that is, a turf with narrower blades, to be more desirable than one with wider, more coarse blades. The turf used on most Illinois putting greens, creeping bentgrass (*Agrostis palustris* L.), has a very narrow leaf blade. It is often thought to produce a higher quality turf than a coarse, pasture grass, such as Alta tall fescue (*Festuca arundinacea* L. 'Alta'). One reason that weeds, such as broadleaf plantain, are so undesirable is that they are much coarser than the turf they invade, and therefore, stand out.

We also perceive denser turf, that is, turf with more aerial shoots in a given area, to be higher in quality. Touchdown Kentucky bluegrass (*Poa pratensis* L. 'Touchdown') is denser than Kenblue Kentucky bluegrass when grown under similar conditions. Any factor that reduces the density of the turf, such as a disease or insect problem, can reduce the quality of turf.

A third visual component of turfgrass quality is color, that is, the measure of light reflected by a grass. Most people prefer darker green turf to lighter, yellow green turf. Knowledge of color characteristics of different species or cultivars is important because the genetic makeup, including color, of different turfgrass species and cultivars can vary greatly. For instance, annual bluegrass (*Poa annua* L.) is naturally more yellow green than many of the Kentucky bluegrass cultivars. The color of turf also depends on the time of year, the general level of fertility, the presence of diseases or insects, and the moisture status of a turf. Large amounts of nitrogen fertilizer applied to a naturally yellow green turfgrass to produce dark green turf, may not darken it. But it may increase its susceptibility to disease.

A high-quality turf appears smooth and evenly cut. A ragged appearance reduces its visual quality.

Turfgrasses have spreading or bunch-type growth habits. Spreading turfgrasses have either rhizomes (below-ground horizontal stems) or stolons (above-ground horizontal stems). Rhizomatous and stoloniferous grasses can form dense matted turfs that will fill areas because of their spreading stems. Bunch-type grasses, when seeded properly, can produce a

dense turf. However, when seedling stands are sparse, turf can appear clumpy. When establishing turf, it is important to seed it at the proper rate.

Together these visual components give uniformity to the overall appearance of a turf. A uniform or even turf is very desirable. It is generally dense and smooth throughout its entire surface, with compatible color, texture, and growth habit. Turfgrasses should be selected and maintained so that uniformity is a priority if high-quality turfgrasses are desired.

Researchers' evaluations improve selection. Faculty and associates in the departments of Horticulture, Plant Pathology, and Agricultural Entomology at the University of Illinois are working on the problems of growing turfgrass so that turf species and cultivars, pesticides, and cultural practices can be selected to provide the highest-quality turf or the best-performing turf for a given situation. For instance, national cultivar evaluations of perennial ryegrass and tall fescue are currently under way on the Urbana campus. The results will be combined with data from other sites to provide national data and will be used to evaluate turfgrasses for use in Illinois. A turfgrass that is well adapted to its site will generally perform better and be of higher quality. The effectiveness of both labeled and experimental pesticides, such as herbicides or fungicides, is tested and evaluated. Other studies test and evaluate turf fertilization, cultivation, and other cultural programs, all in the name of higher-quality turf.

Whether we are sitting in a lawn chair in a small lawn area, driving along an interstate highway, playing football with the neighborhood children, or sitting in the left field bleachers at Wrigley Field, we benefit almost daily from the presence of turfgrass in our human environment. We should try not to take it for granted.

Thomas Voigt, assistant horticulturist, Turfgrass Extension, and Thomas Fermanian, associate professor of turfgrass science, Department of Horticulture

In Progress

Economic Returns to Agricultural Research

The following abstract summarizes the presentation by Bobby R. Eddleman, the director of the Agricultural Research and Extension Center, Texas A&M University, Corpus Christi, during the symposium held in honor of the Centennial of the Illinois Agricultural Experiment Station. A summary of the other major symposium presentation will appear in a subsequent issue.

Studies of the returns to investments in agricultural research allow us to draw certain general conclusions. The first is that research supported by the public sector has accounted for one-fourth of the growth in the total productivity of U.S. agriculture over the past four decades. An additional one-fourth of this growth has come from investments in extension and formal education. This production coefficient for research on aggregate agricultural productivity has remained relatively stable over the past three decades. Other factors accounting for the remaining one-half of the growth in farm productivity include research and development activities of the private sector; organizational, communications, accounting, and managerial progress; more efficient transportation; and economies of scale and specialization in agricultural production.

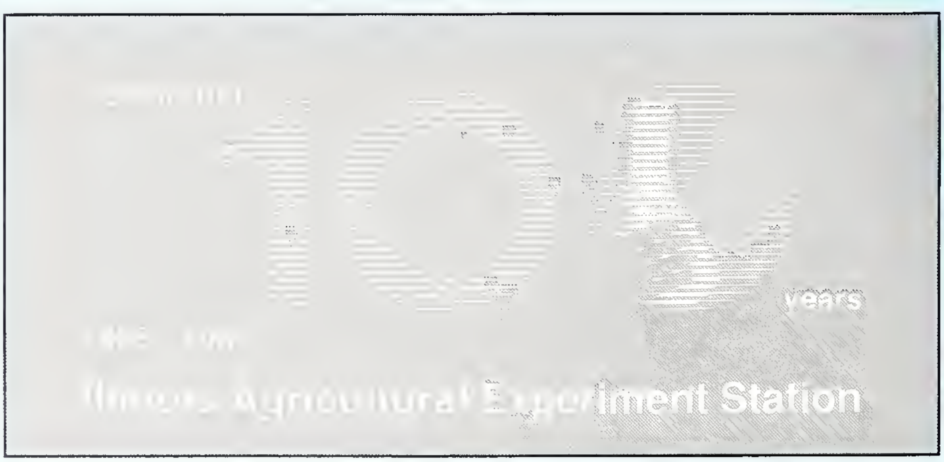
We can also conclude that agricultural research has produced enough added value in the farm and food system to yield extraordinarily high rates of return to research investments, on the order of 30 to 50 percent annually. But underinvestment in public agricultural research has been the typical pattern. High rates of return and low levels of investment are indicative of underinvestment in agricultural research by the public sector. Other factors being equal, increased public investment in research will benefit society up to the point where returns to investment in research equal returns to alternative investments.

These studies have also indicated that annual return to research on animals and animal products over the past two decades has compared favorably with returns to research on individual crop commodities and on ways to increase aggregate crop and livestock production. With the exception of poultry research, it appears that additional research in animal agriculture to improve the productivity of nonconsumed inputs (value added) in the production process may be more fruitful than research to improve the productivity of consumed inputs.

According to these studies, benefits from investment in public-sector research spill over from one state or region to another through the interregional transfer of technology. These externalities, or spill-over effects, may weaken farmer support for agricultural research and partially account for underinvestment in public-sector agricultural research. Much of the benefits from agricultural research spills over to consumers in other states and nations also through interstate and international trade in farm products. But the benefits for each family are not large enough for the individual American consumer to feel the connection. This seeming lack of impact may weaken consumer support for agricultural research.

For the major commodity-producing sectors of U.S. agriculture whose products enter international trade, we may need to justify future productivity-enhancing or input-saving research in terms of maintaining the competitive position of these sectors in world agriculture rather than in terms of their spill-over benefits for the American consumer. For other commodity sectors oriented to the U.S. domestic market, productivity-enhancing research can be expected to benefit American consumers substantially, with the greatest relative impact on the lower-income strata.

Even though large increases in public support for agricultural research have been difficult to obtain, state agricultural experiment stations and the USDA have continued with available resources to support research programs that are of great benefit to society. These research programs have paid off in benefits to people in all walks of life, and they have paid off very well indeed.



New Honey Bee Pest Found in the United States

Varroa jacobsoni (Oudemans), one of the most serious pests of the honey bee, was found for the first time in North America in honey bee colonies in Wisconsin on September 25, 1987. Since then, the mite has been identified in Illinois and 16 other states. It is seriously threatening the beekeeping industry and the many food and farm crops that depend directly or indirectly upon honey bees for pollination.

This external parasitic mite feeds on the blood of brood or developing bees as well as that of adult bees. The feeding decreases the brood, deforms the bees, and generally weakens the entire colony.

Reddish brown, adult female mites are oval and flat in shape. About 1.1 millimeters long by 1.6 millimeters wide or the size of a pinhead, an adult female mite can be seen with the naked eye. Only females are found on adult bees. Rarely encountered outside the brood cells, the white to yellowish males are nearly round and measure from about 0.80 to 0.97 millimeter across.

Eugene Killion, a University of Illinois Extension specialist in apiculture, has been collaborating on experiments with the United States Department of Agriculture Animal Plant Health Inspection Service (USDA-APHIS) and the Agricultural Research Service of the USDA. The experiments have involved the use of various miticides and tobacco as well as mite detector inserts that were developed by DeWill, Inc., Elmhurst, Illinois. The results of these and other experiments are being used to make recommendations by the USDA-APHIS for the U.S. beekeeping industry. These recommendations enable state regulatory agencies to conduct surveys and to certify the intrastate and interstate movement of beehives for the production of both honey and pollen and for pollination services.

Inserting an Apistan strip — a plastic strip that is impregnated with fluvalinate. The recommended survey procedure calls for inserting Apistan strips into the broodnest area after a mite detector containing a white, sticky paper has been inserted on the floor of the bottom board of a bee colony (above).

Female Varroa mite (left).

Removing a mite detector (below).

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Fall 1988

Conservation of Natural Resources

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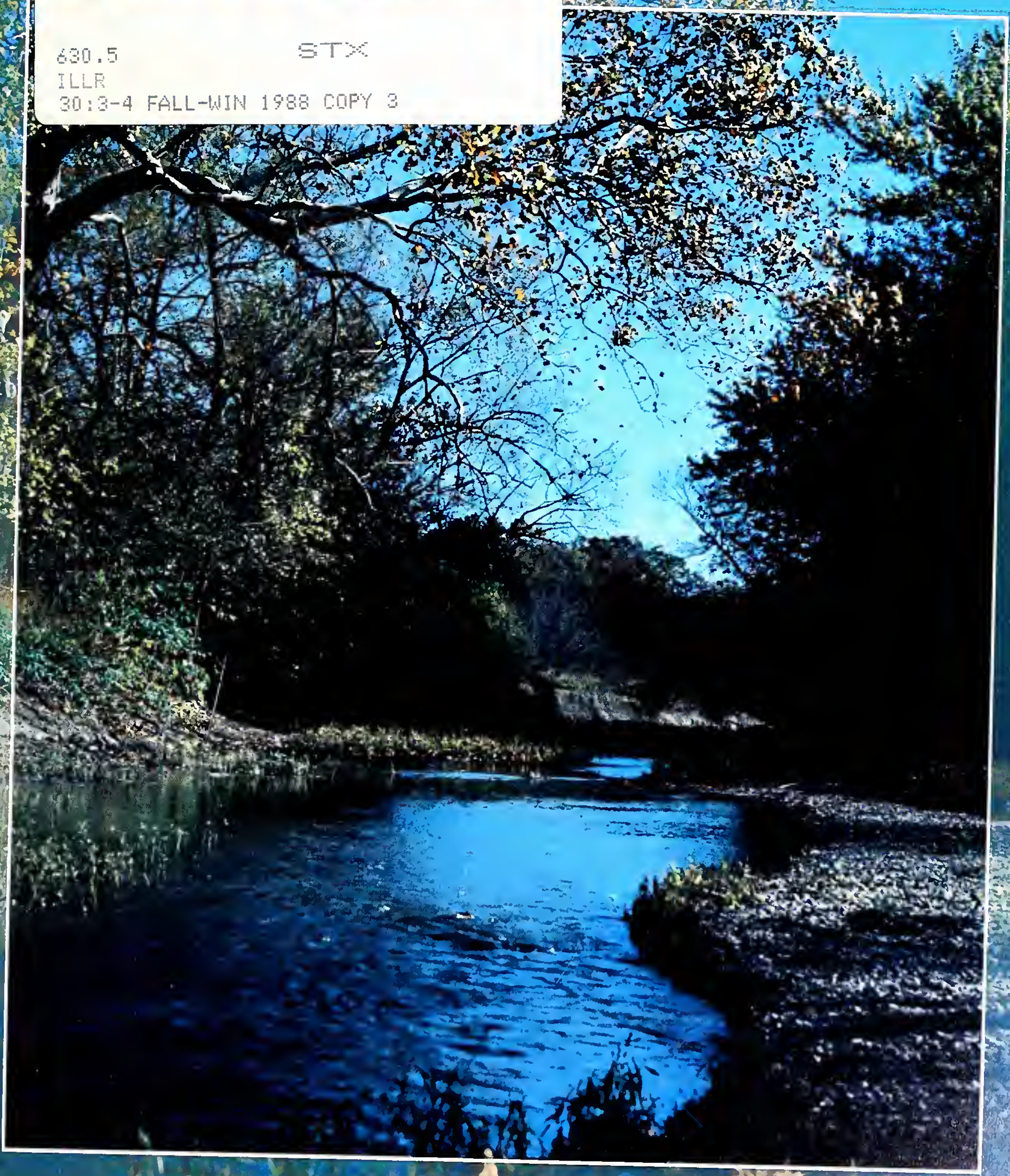

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 30, Numbers 3/4

The Cover

The beauty of these fall reflections in the Middle Fork of the Vermilion River, Ford County, Illinois, reminds us of how much we stand to lose if we fail to conserve our natural resources and preserve the harmony between people and the land.

"At a time unlike any in the past, we must envision the future."

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10 M

George E. McKibben

George E. McKibben, one of the first agronomists to study and advocate no-till crop production, died February 1, 1988. Throughout his career, McKibben promoted no-till soil management and crop production practices. This work has been called the single most important contribution to corn production since the development and adaptation of hybrid seed corn.

Educated at the University of Illinois, McKibben joined the faculty of the College of Agriculture in 1946. He enjoyed international renown as a professor of crop and soil management at the Dixon Springs Agricultural Center (DSAC) until his retirement in 1983. On several occasions, he served as acting director of the center.

McKibben was especially interested in applying conservation tillage methods to the conditions that exist in southern Illinois. At Dixon Springs, he was able to demonstrate the potential for high corn yields when no-till production practices are used.

He chaired the Agronomy Field Day at DSAC for many years, and his experimental plots generated such interest that hundreds of visitors from Illinois and nearby states attended this event.

The original no-till research plots at Dixon Springs were named the "McKibben Plots" during Agronomy Day in 1983. Established in 1966, these plots are among the oldest, continuous no-till plots in the world.

McKibben's long-term commitment to conservation has enhanced all of our lives and provided a basis for future research. We are grateful, and we dedicate this issue of *Illinois Research* to his memory.

Illinois Research

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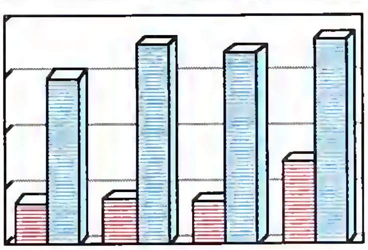
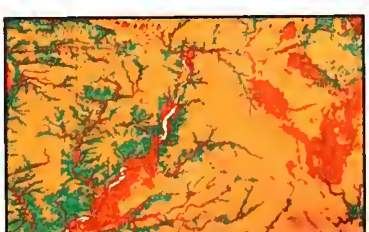



1988 – Directions – 1998

Conservation-Oriented Production Systems Can Help Sustain Illinois's Agricultural Base

Inscribed on the west wall of Davenport Hall at the University of Illinois is the statement of Andrew S. Draper, President of the University in 1894: "The wealth of Illinois is in her soil, and her strength lies in its intelligent development." Some persons might disagree with that statement today, but for those involved in production agriculture, the statement is as true today as it was almost 100 years ago. That is the reason many private and public, local, state, and federal conservation-minded organizations and agencies have joined together to develop and implement programs to use wisely the great soil resources that we have in Illinois. A great deal of the credit for the development of conservation-oriented production systems goes to the farmer-producer families. Their continued dedication and support have been the most important factor in the successful maintenance of these state resources.

If Illinois is to achieve its goals for soil erosion, water quality, and sediment reduction, existing soil-conserving production systems must be further refined to provide for consistent levels of performance, and new methods must be studied and developed. When combined with existing systems, these methods will provide Illinois's farmers with the broadest possible range of production systems to meet their varied needs.

One such soil-conserving production system currently used by Illinois farmers is conservation tillage. In the broadest sense, the term, "conservation tillage," includes many different systems approaches to conserving the soil base while producing a salable commodity. While some form of conservation is being practiced on a reported 8.9 million acres of Illinois cropland, not every system will work everywhere for everybody every year. We must continue to develop the knowledge base for this program while utilizing the knowledge gained to develop new, innovative production systems.

The development and refinement of additional low-cost production systems, which farmers can readily adopt without extensive changes or modifications in their existing equipment, will help ensure a sustainable agricultural base for the State and for its future generations.

In this issue of *Illinois Research*, conservation tillage is discussed from a number of different perspectives by those who are in the forefront of research and extension programs that deal with this important subject.

Larry A. Werries, director, Illinois Department of Agriculture

Vital Connections Within the Land Community

Robert J. Reber and Peter D. Bloome

Sugar maple along West Creek, Ten Mile Grove, Ford County, Illinois.

The first principle of ecology holds that all things are interconnected. This interconnection explains why the adoption of new technology always produces unforeseen as well as desirable changes. Frequently, the unforeseen changes have negative environmental impacts.

Commercial fertilizers provide an example. Plentiful, relatively inexpensive commercial fertilizers — particularly nitrogen fertilizers — have made agriculture more intensive and more productive. Crop rotations are no longer required to maintain soil fertility, allowing continuous production of row crops. Forages have been dropped from cropping systems, followed by the livestock enterprises that utilized these forages and the nutrient recycling afforded by manure.

Commercial fertilizers have also had an impact on the environment. The movement of these fertilizers into groundwater and surface water is causing increased concern. Currently, nitrates are the biggest concern. At the same time, intensive row-crop production has greatly increased soil erosion.

Chemical pesticides offer another example of the impact of technology. Herbicides reduce the need for mechanical weed control, allowing control of soil erosion even in intensive cropping systems. But trace amounts of these chemicals are now widely present in groundwater and surface water.

Insecticides have also improved agricultural production and product quality, but insecticides affect beneficial as well as pest insects. And the insects demonstrate a remarkable capacity to adapt because extensive use of insecticides serves to select resistance from the insect population. Furthermore, because most insect pests exist near the bottom of the food chain, the use of insecticides can affect the entire chain.

A primary consideration for adopting or adapting any technology must be its potential environmental impact because we are bonded to the soil and the pyramid of plants and animals it supports. The phrase, "from dust to dust," gives insight into our existence beyond the theological. To deny our dependence on the land community — the soil, water, air, and all biologic species — either through ignorance or greed invites disaster. Our hope for a sustainable society depends upon our commitment to understand and honor our vital connections with nature.

If we see ourselves in a mutually supportive relationship with the rest of nature, a question arises. How do we judge the appropriateness of our actions toward the natural environment? Should ethical considerations direct our actions? If so, what should they be?

The search for a meaningful, workable environmental ethic is not a new venture. One such formulation that is receiving renewed acclaim is the Land Ethic proposed by Aldo Leopold in 1947, one year before his death. Leopold spent a lifetime studying the interrelationships of ecology, aesthetics, and ethics (Flader 1974). His Land Ethic was the conclusion of these observations. His ethic states simply: "A thing is right when it tends to preserve the

integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" (Leopold 1987).

It is popular to assume, however, that humans have dominance over the rest of nature and that the natural environment exists only as a resource to serve us (Devall and Sessions 1985). Leopold's view is radically different. In a single stroke, this novel biocentric ethic "changes the role of *Homo sapiens* from conqueror of the land community to plain member and citizen of it" (Callicott 1982). It also implies that all of nature has intrinsic worth whether it has any apparent contemporary economic value or not: every small cog and wheel in each ecosystem is good because it is a part of the whole (Leopold 1966). As a logical extension of this ethic, he defines conservation as a state of harmony between people and the land (Leopold 1987).

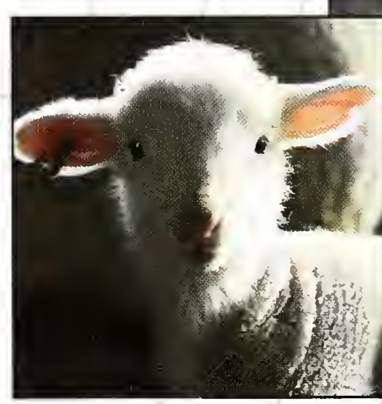
The Land Ethic has been criticized as being too idealistic and impractical. Although there may be some truth in these criticisms, this ethic provides a standard, a goal to strive toward. And, in a sense, the striving may be most important.

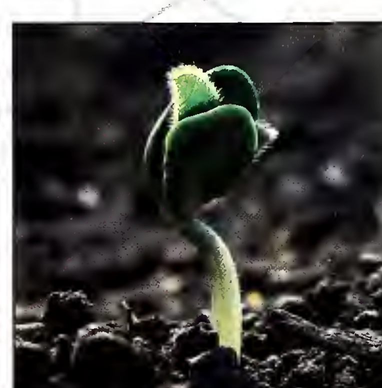
Even though this ethic considers the wholeness of nature and what is good for the whole, those who believe in human dominance can see benefits for humans. The ageless axiom, "Like begets like," applies here. Integrity begets integrity, and stability promotes stability. By protecting these traits of the natural environment, we gain as an integral part of this complex, biotic community. Preserving the stability of soil and the integrity of water is essential for all species, including our own. Beauty begets beauty. Protecting and experiencing natural beauty give us time to reflect upon and to experience a renewal of spirit — to become more beautiful people.

From past observations, we know that our actions toward the natural environment should not be guided totally by short-term economic self-interest. A moral relationship ought to exist between humans and the rest of nature if the land and the environment are to be viewed as something more than mere economic commodities. Leopold's insight provides us with the practical basis for this moral relationship, sustaining the health of the land community, that is, its capacity for self-renewal. The decisions we make as individuals and the policies we adopt collectively ought to have ethical underpinnings. These vital connections with the rest of the natural environment must be protected. To do less diminishes our moral strength and jeopardizes our material future.

This issue of *Illinois Research* concerns the conservation of natural resources and more specifically, conservation tillage. What part can this practice play in achieving the mutually compatible, desirable goals of maintaining agricultural productivity and protecting these vital connections within the natural environment? Are there possible unforeseen outcomes from using this technology? How can conservation tillage be combined with other strategies to achieve desired goals? Both basic and applied research will be needed to answer these questions. And the strategies that evolve will be limited only by our imagination and ingenuity.

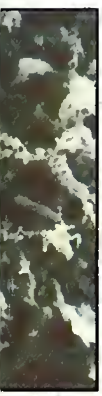
Robert J. Reber, associate professor of nutrition, School of Human Resources and Family Studies, and Peter D. Bloome, assistant director, Illinois Cooperative Extension Service

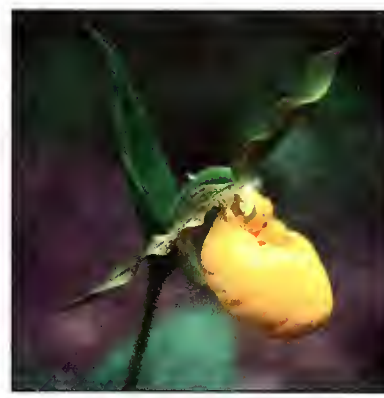




"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise" — Aldo Leopold, 1947

"Man did not weave the web of life, he is merely a strand in it. Whatever he does to the web, he does to himself." — Chief Seattle, 1854





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Photos by Robert Reber on pages 3, 4, and 5. Photo of sulfur bacteria on page 4 by Rick Olson of the Center for Electron Microscopy. Photo of the grey fox on page 5 by Michael R. Jeffords.

Tillage Systems: Considerations Based on Erosion, Crop Production, and Costs

John C. Siemens and J. Kent Mitchell

Tillage operations influence virtually every aspect of crop production. The number of variables that impact decisions in selecting a tillage system is great, and the year-to-year variations are large. Most generally, to simplify decisions about tillage systems, the farmer must consider three major factors: erosion, crop production, and costs.

To briefly consider the latter two factors first, crop production, or yield, is directly related to income; we can figure the profit realized by subtracting the production costs from the income received.

Along with the desire to select a system that will maximize profit, the producer's choice of tillage system is also significantly influenced by the relative potential for soil erosion. And provisions of the Food Security Act of 1985 contain specific soil erosion limits that will affect the choice of tillage operations used on soils regarded as highly erodible.

Clearly, the three major factors — erosion, yield, and costs — can enter into some elaborate equations; and with the range of available equipment, crop producers can formulate almost any imaginable tillage system.

The more common primary tillage tools include the moldboard plow, chisel plow, subsoiler, and offset disk. Common secondary tools include the disk harrow, field cultivator, and combination tool.

Special attachments allow planters and drills to operate in untilled fields, where all of the previous crop residue remains on or near the soil surface. In addition to conventional row cultivators, some row cultivators will operate through a lot of plant residue on the soil surface.

Simulated rain storms test erosion control

Tillage systems that help reduce soil erosion are referred to as conservation tillage systems, commonly defined as those systems that leave at least 30 percent of the soil surface covered with residue after planting.

In effect, such systems reduce soil erosion. To determine just how effectively, researchers at the University of Illinois use a rainfall simulator to apply intense "rain storms" to plots treated with various tillage systems. Results from work with the rainfall simulator are being used to update the Universal Soil Loss Equation (USLE), which is commonly used to estimate soil loss from agricultural fields under various conservation practices.

Results on sloping sites. In recent years, researchers conducted numerous simulator comparisons on corn and soybean plots on sloping sites. In one comparison, of the first 2.5 inches of water applied following corn harvest, the runoff was 1.0 inch from the moldboard-plow treatment and 0.9 inch from both the chisel-plow and no-tillage conditions (Figure 1). In all three treatments, tilling and planting on the contour cut runoff almost in half.

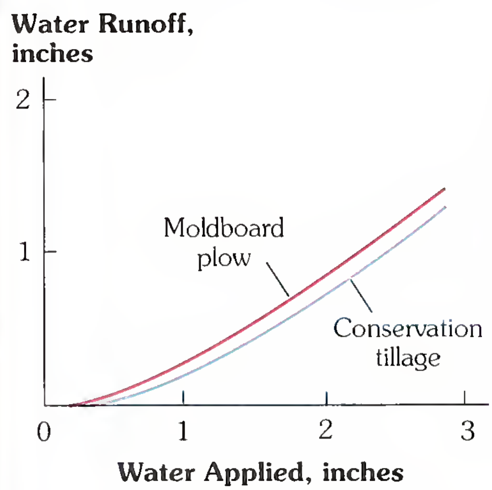


Figure 1. Water runoff from plots that were planted to corn the previous year.

Note: Multiply inches by 25.4 to get mm (millimeters).

Soil loss was by far greatest from plots that were moldboard plowed. Following corn harvest, the first 2.5 inches of water applied carried away 7 tons of soil per acre from the fall moldboard-plow treatment, compared to 1.6 tons for the chisel-plow treatment and 0.2 tons with no tillage (Figure 2). Overall, soil loss was reduced by more than half when the tilling and planting were performed on the contour.

Across systems, soil loss greater following soybeans. Whatever the tillage system — moldboard plow, chisel plow, or no tillage — soil loss was greater following soybeans than following corn. Both the larger quan-

tity of residue left in the field after corn and the relatively loose, easily erodible soil following soybeans account for the greater soil losses after soybeans.

Specifically, with 2.5 inches of rain on plots that were planted in soybeans the previous year, the soil loss was more than 13 tons per acre with the moldboard-plow treatment, 4.3 tons with chisel plow, and 1.5 tons with no tillage.

How tillage-related variables affect yield

Numerous factors affected by tillage practices can influence yield: plant population, soil compaction, soil temperature, nutrient distribution, weed control, and insect control. In addition, the weather (particularly rainfall) and other factors such as soil type and location affect yield (Figure 3).

In tillage experiments with corn and soybeans, researchers at the Illinois Agricultural Experiment Station continue to evaluate these complex variables. In most of these studies, yields are not different between moldboard-plow, chisel-plow, and disk systems when corn and soybeans are rotated. With continuous corn, yields often decrease slightly as tillage is reduced. With continuous no tillage, yields are sometimes less.

Expect equivalent stands. Given the planters and drills available for seeding with conservation tillage, actual plant stands are usually equivalent under the various tillage systems. With any system, unfavorable weather and equipment that

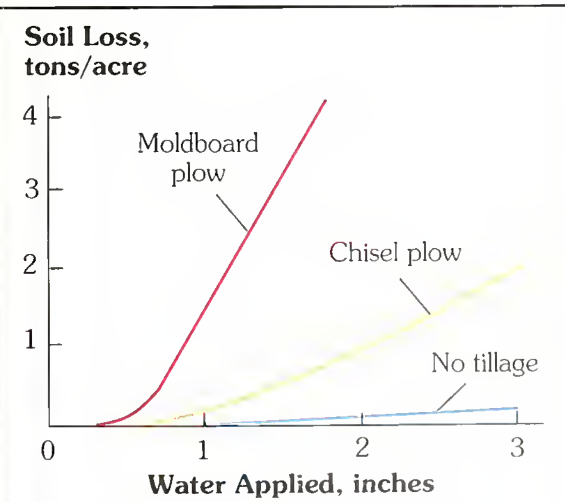


Figure 2. Soil loss from plots that were planted to corn the previous year.

Note: Multiply tons/acre by 2.2417 to get t/ha, (metric tons per hectare). Multiply inches by 25.4 to get mm (millimeters).

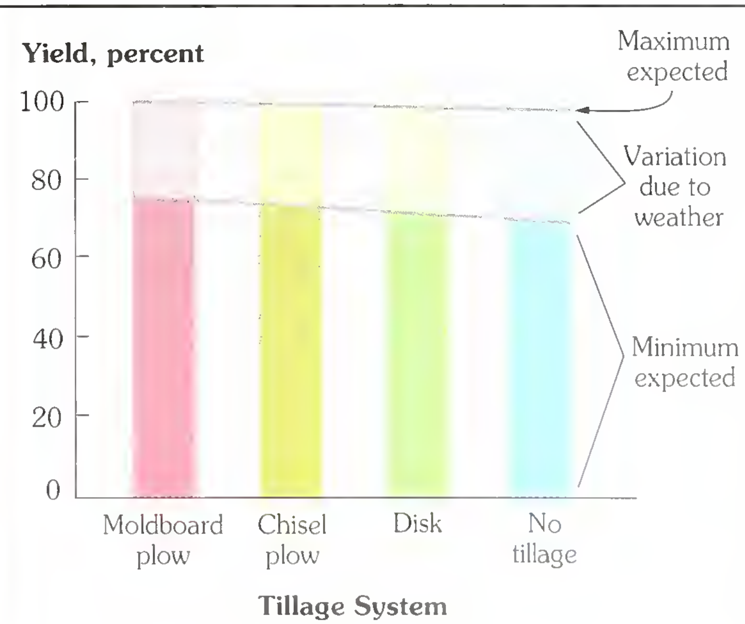


Figure 3. Expected yield with different tillage systems.

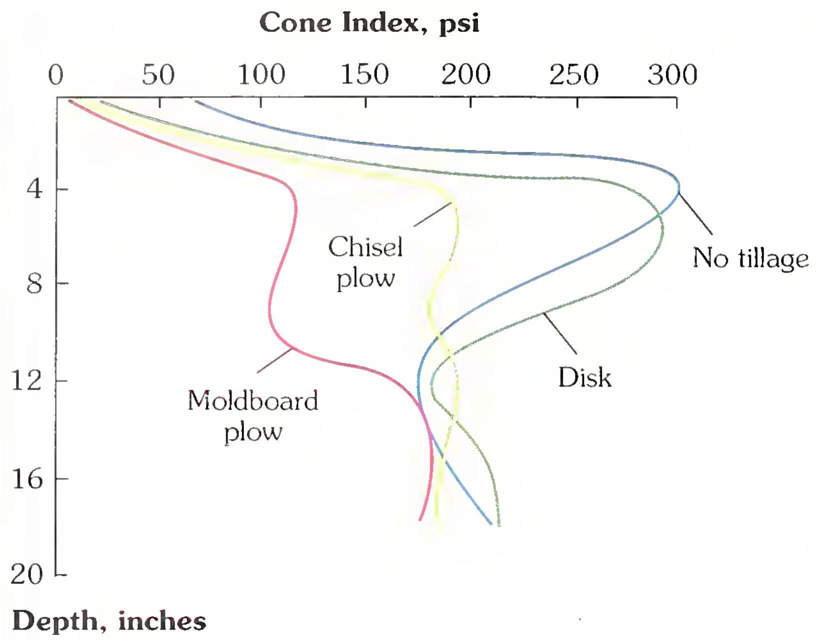


Figure 4. Cone penetrometer readings from four tillage systems: the greater the reading, the greater the soil compaction.

Note: Multiply inches by 25.4 to get mm (millimeters). Multiply psi (pounds per square inch) by 6.894757 to get kPa (kilopascals).

is not properly adjusted for soil conditions may affect stands.

As tillage is reduced, measurements indicate that soil density increases (Figure 4). Although increased soil density is reported to slow root development and to reduce yields, we do not completely understand how soil compaction affects plant growth.

The increased plant residue that remains on the soil surface as tillage is reduced works with other factors — possibly less soil aeration and greater soil moisture — to decrease the rate at which the soil warms up in the spring (Figure 5). This slower warming of the soil slows both crop emergence and early plant growth and can decrease crop yield.

Questions of long-term effects. Even nutrient distribution in the soil may be affected by the choice of tillage system. Phosphorus (P) and potassium (K) fertilizers and limestone are usually applied to the soil surface and do not move into the soil with water as does nitrogen (N) fertilizer. The moldboard-plow system mixes the tilled layer; but the chisel-plow, disk, no-tillage, and several other reduced tillage systems do not mix the nutrients into the soil as well (Figure 6).

After a few years, this lessened mixing results in high concentrations of P, K, and limestone near the soil surface and low concentrations in the lower portions of the tilled layer. The degree to which the nonuniform distribution affects crop yield is not clear. Intuitively, though, it seems that the low concentrations in the lower parts of the tilled layer could cause a yield decrease, especially in a dry year.

Pest control. Whatever the tillage system, weeds must be controlled to obtain profitable yield levels. Generally, as tillage is reduced, infestations of perennial weeds and grasses increase. Despite this increased threat, herbicide performance (percentage control) appears to be unaffected by the tillage system used.

If incorporated herbicides are eliminated, however, weed control often becomes more directly weather related. In addition, because mechanical control may not be an option, fewer alternatives are

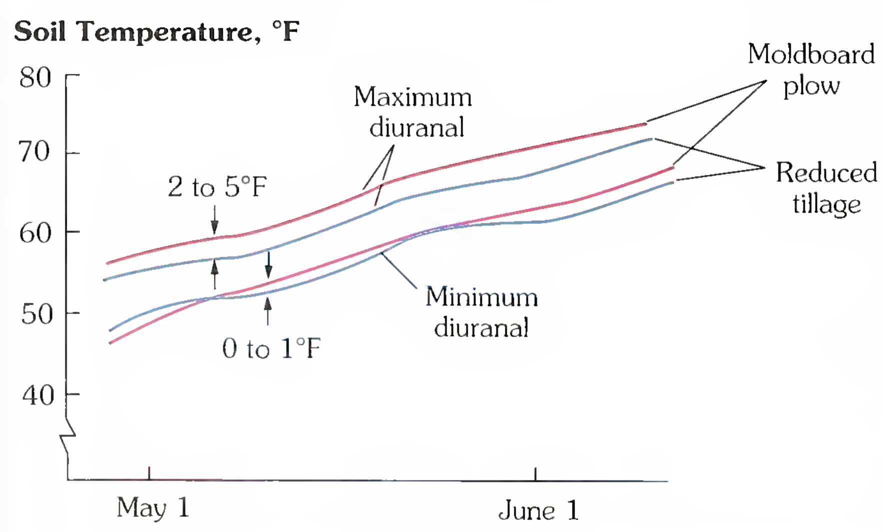


Figure 5. Daily temperature variation with moldbord plow and reduced tillage systems.

Note: $T_C = (T_F - 32)/1.8$

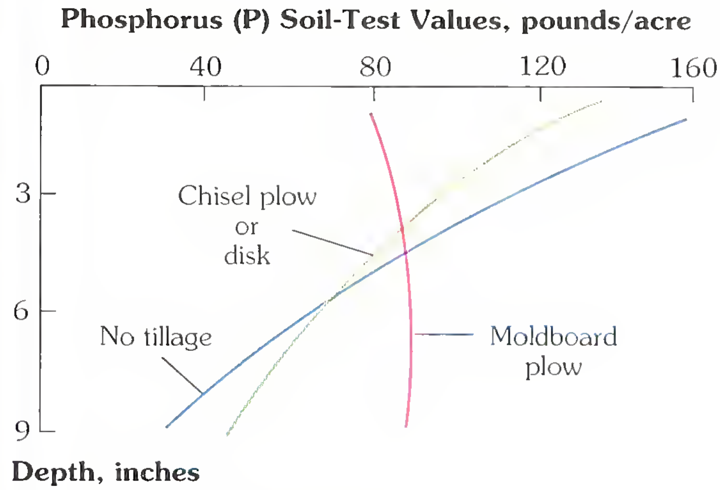


Figure 6. Variation in phosphorus soil-test values with depth for four tillage systems. Each tillage system had been used for 6 years, with phosphorus surface applied.

Note: Multiply pounds/acre by 0.89 to get kg/ha (kilograms per hectare).

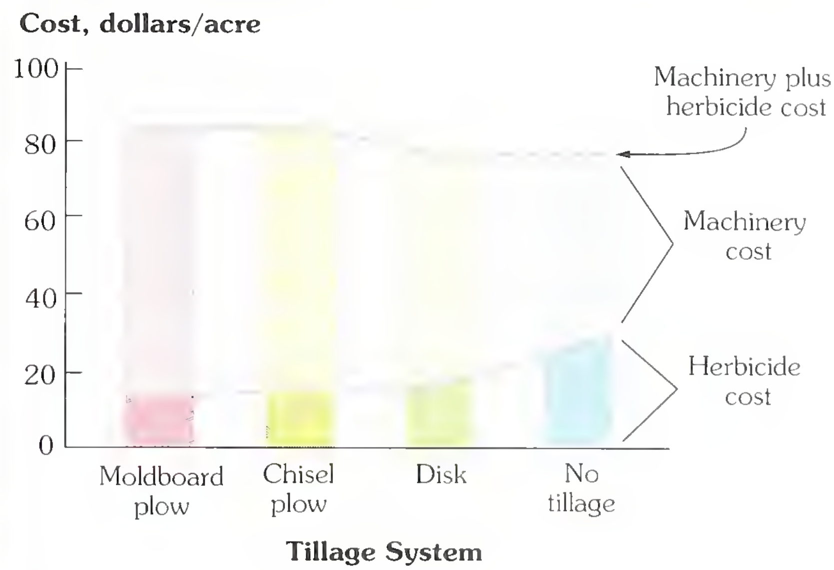


Figure 7. Cost trends for machinery and herbicides with different tillage systems.

available — making it even more important to give careful thought to weed management considerations.

Insect pests are not likely to be a limiting factor in using reduced tillage systems. Because of the increased potential for insect pest problems with reduced tillage, however, the need for insecticides to suppress outbreaks will likely increase.

The bottom line — trade-offs

To compare the costs of different tillage systems, you must determine the inputs affected, primarily those related to machinery, pesticides, and possibly nitrogen fertilizer. By comparison, costs for land, seed, and other inputs are usually the same with any tillage system.

Costs related to machinery include the fixed and variable machinery costs, any applicable labor costs, and costs due to untimely field operations. If the selected tillage system requires a dry or liquid form of nitrogen fertilizer in place of the less expensive anhydrous ammonia, this cost difference should also be included.

Generally, as the amount of tillage is reduced, machinery-related costs decrease and pesticide costs increase. If we consider only machinery and pesticides, total costs usually decrease slightly as tillage is reduced (Figure 7).

A more complete cost analysis would also include the cost of the soil lost to erosion. This cost is difficult to quantify as data are incomplete for defining the yield reductions due to loss of topsoil. Also, important off-site costs of sediment include sediment-filled drainage ditches and lost reservoir capacity.

To summarize, determining the best tillage system for a specific location, crop, and soil is not an easy task. As the amount of tillage is reduced, the total production costs can be decreased. If the reduced tillage system is to be more profitable, though, the savings in cost must be greater than the value of any decrease in yield. Especially on sloping fields, the greatly reduced soil erosion resulting from reduced or conservation tillage is an important factor to consider. In the case of highly erodible soils, the conservation compliance provisions of the Food and Security Act of 1985 will probably require the use of conservation tillage. Because conservation tillage is so effective in erosion control, we must continue our efforts to make conservation tillage an accepted and satisfactory alternative to conventional tillage.

John C. Siemens and J. Kent Mitchell, professors of agricultural engineering

Soil-Conservation Provisions Challenge Advisers

Donald Meyer

Helping Illinois farmers meet the Farm Bill's soil-conservation provisions for the 1990s is one of the biggest educational challenges facing county Extension advisers. This challenge, however, is also an opportunity for county staff to demonstrate leadership to farm operators and owners.

One of the simplest methods of meeting this challenge and bringing most farmers on highly erodible land into compliance with erosion-control provisions of the bill is to convert to a seriously reduced method of tillage or to no-till. Many farmers in McLean County and across the state have already begun to experiment by adopting a lower-tillage-and-higher-management approach.

We advisers have a tremendous opportunity to help our cooperators change tillage practices; but, to gain the competence we need for this task, researchers must first provide us with some basic information.

Information gap in counties

It has been a long time since the demand for education from our grass-roots cooperators has been so great. One of the strengths of the Extension service is that we advisers not only share the information gained from university research with producers on the farm, but we also reflect the need for information back to the university. We must gear up with adequate research to fulfill the current need. Let us recognize the needs of our county agriculturists and allow the system to work.

Interdepartmental cooperation needed

We must look at the coming change in tillage methods not merely as an engineering problem. Affecting the on-farm application of economics, entomology, weed science, fertility, and pathology, this change is not just a simple change in machinery, as in switching from planting to drilling soybeans. Conversion to no-till or to a low-tillage method will require further research across interdepartmental lines.

Giving the whole picture

Because the adoption of no-till or a low-tillage method is a complex issue and because each producer's situation is unique, we need to research this issue fully and to stand ready to share all the pros and cons of making this change in individual situations. Farmers are continual risk-takers: rather than being told that they can or cannot try something new, they want and need to know up front all of the risks involved so that they can make the final decision. Researchers can and must inform county staff so that they can present the facts necessary for informed decision making.

Is it a trade-off?

As we consider less reliance on tillage to control erosion, it seems that we might end up relying to a great extent on chemical controls and possibly polluting our groundwater. Are we trying to contain one crisis by contributing to another? Further studies must be conducted to determine whether we are conserving soil but risking damage to the environment.

The bottom line is that we need to pursue the issue of less tillage, but we may need to compromise before no-till can be universally adopted. The complete solution may be a combination of traditional tillage with no-till.

Out in the counties, we are still learning by trial and error. Now more than ever, we need help from an unbiased research base. Research information must be made available to Extension advisers so that we can communicate it and help formulate solutions to the problem of erosion for the future of agriculture in Illinois and for our survival in 1990 and beyond.

Donald Meyer, Extension adviser, agriculture, McLean County, Illinois

Formerly buried or burned, corn stubble plays an important role in the conservation of soil.

Effects of Agrochemicals in Conservation Tillage on the Environment

Allan S. Felsot, Louis F. Welch, William S. Curran, Ellery L. Knake, and William G. Ruesink

Fertilizers and pesticides have been considered fundamental inputs for maximizing corn and soybean yields in Illinois regardless of the type of tillage system used. We know now, however, that some agrochemicals have harmed the environment. For example, the widespread use of DDT in the 1950s led to residues that have contributed to the decline of some predatory birds.

Today, contamination of both surface water and groundwater by pesticides or nitrates has caused renewed concern about the continued widespread use of these chemicals. Current uneasiness is due to the impact conservation tillage will have on the intensity of agrochemical use and the possibility of more environmental contamination.

Extensive use of commercial fertilizers in Illinois on crops like corn and wheat is a relatively new management practice. More than 90 percent of the fertilizer nitrogen used in Illinois is applied to corn. As shown in the figure, in 1987, fertilizer supplied an average of 158 pounds of nitrogen per acre to Illinois corn; in 1950, it supplied 3.

The use of phosphorus and potassium fertilizer has also increased rapidly since 1950, but because of their properties and behavior in soils, their potential adverse effects on groundwater supplies appear to be nil as compared to those of nitrogen.

Because modern farming practices are so dependent on these and other agrochemical inputs, it is unrealistic to believe that such inputs will soon be completely eliminated. It is hoped that basic research on subjects ranging from biotechnology to insect ecology and from crop physiology to soil microbiology will provide the basis for a less chemically dependent future. Until feasible replacement technologies are thoroughly investigated, we can minimize the adverse impacts of agrochemicals with better management techniques.

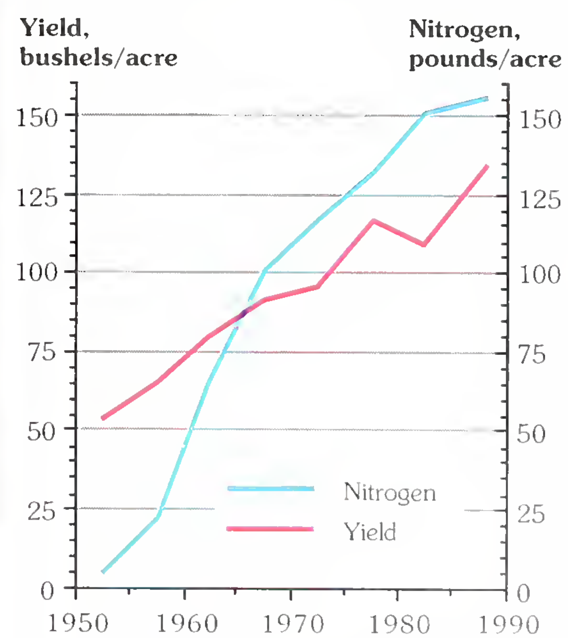
Wise management of fertilizers

Fertilizers differ from other chemicals used in crop production in that they are added to replenish elements that are beneficial to crops but that are not present in soils in adequate supply.

Nitrogen is the mineral element that is required in the largest amounts by most crop plants for good growth. Most agricultural soils cannot supply for many seasons the large amounts of nitrogen needed by nonleguminous plants for high yields. For many years, growers have applied animal wastes to soils and grown legumes to keep soils productive. Interested in producing crops at the lowest cost per bushel or ton, however, they now rely on nitrogen fertilizer because this practice is more profitable than using "homegrown" nitrogen from legumes.

Efficient use of crop inputs is necessary if Illinois farmers are to compete in the world marketplace, a goal that is compatible with minimizing the adverse effects of fertilizers on water quality. Management practices that increase crop uptake of applied nitrogen fertilizer also reduce the amount of nitrogen that is available to enter water supplies.

Calculating fertilizer loss. Although accurately predicting the amount of fertilizer entering water supplies is difficult, much is known about the behavior of fertilizers and the diverse



Relationship of Illinois Corn Yields to Applications of Fertilizer Nitrogen, 1950 to 1987.*

**Plotted values are the averages for 5-year periods.*

Adding nitrogen fertilizer to Illinois soils. Illinois farmers use 10 percent of all the nitrogen fertilizer used in the United States.

characteristics of Illinois soils. This knowledge facilitates the development of management practices for reducing the potential adverse effects of fertilizers on the environment. For instance, phosphorus and potassium are lost from soils primarily by erosion. Therefore, reducing erosion — the goal of conservation tillage — also reduces the loss of phosphorus and potassium.

Nitrogen can be lost from field soils not only by erosion, but also by volatilization after denitrification and by leaching to groundwater. Leaching of nitrogen as nitrate from the upper soil profile is the principal pathway by which lost nitrogen can harm water quality. Leached nitrogen is costly to farmers because it cannot benefit the crop for which it was intended. The amount of nitrogen that enters groundwater depends both on the amount of water that moves through the upper soil to reach the groundwater and on the concentration of nitrogen in that water. Complete agreement does not exist about how conservation tillage affects the amount of nitrogen that leaches from soil in comparison to other tillage practices. Some researchers hold that in slowing the movement of surface water from field soils, conservation tillage increases the penetration of water into the soil. The greater the amount of water entering the soil, the more water is available for leaching nitrogen. Others hold that the moisture and low oxygen conditions characteristic of the wetter surface found with conservation tillage may cause more denitrification and less leaching.

Effective nitrogen management. The goal of good nitrogen management is a low concentration of nitrate in the soil when water is moving below the rooting depth of crops. To reduce the potential adverse effects of unused nitrogen, follow practices that increase the efficiency of nitrogen utilization by crops.

- Be realistic about the amount of fertilizer nitrogen to be applied. Set an attainable yield goal based on yield history for your soils and management practices. Take into account the nitrogen that may remain unused in the soil after a previous application and the amount supplied by manure, sewage sludge, and legumes.
- Do not add nitrogen fertilizer at long intervals before uptake by crops. The longer nitrate is in soil the greater the possibility for leaching.
- Increase the time that added nitrogen is in a form that does not readily leach. Ammonium leaches much less than nitrate.
- Seed plants that grow in cool weather to absorb inorganic nitrogen remaining in the soil after corn maturity. Although this practice has been largely untested, planting cover crops is very compatible with the goals of soil and water conservation. During a droughty year, however, a green winter cover crop could result in a dry soil at corn planting time.
- Consider planting crops that do not demand a lot of nitrogen. Some Illinois soils allow excessive leaching of nitrogen even with good management because of their coarse texture or some other property. If nitrogen concentrations in water supplies are identified as adversely high, crops that do not have a high demand for nitrogen fertilizer may have to be considered for the affected area.

Crop protection

From field to field and from year to year, pest problems vary because of variations in soil type, tillage practices, cultivar or hybrid selection, cropping sequences, surrounding vegetation, previous pest-control practices, and weather. The agricultural ecosystems of these fields are similar, however, in how they differ from natural ecosystems: they lack species diversity, and their soil is disturbed seasonally.

Reducing tillage diversifies agroecosystems because it produces new habitats and long-term changes in the soil surface. These changes need not intensify current weed and insect infestations or cause new pest problems.

Integrated pest management. IPM is the intelligent selection and use of pest-control actions that will ensure favorable economical, ecological, and sociological consequences. Weed scientists and entomologists overwhelmingly agree that regardless of the tillage system, the adoption of the IPM philosophy leads to crop-protection practices compatible with environmental protection.

The first principle of IPM is that a farm is a complex ecosystem in which all factors are interdependent and interacting. Successful pest management requires a thorough understanding of the biological and physical relationships in the system.

Planning is essential to this success. Potential pest problems must be antici-

In this field of soybeans following corn at the Orr Center, Pike County, Illinois, the plot to the left was no-till; the plot to the right was moldboard plowed.

pated, the most compatible crop varieties must be selected, and pest populations must be monitored to determine if they are large enough to cause economic damage to the crop. Economic thresholds are being developed to help farmers determine when to act to control a pest.

Rotating crops and planting resistant varieties number among the effective non-chemical tools for managing pests. Pesticides should be used as a last resort, when other tools are ineffective or unavailable. Judicious use of pesticides will help conserve parasites and predators (natural enemies) of insect pests, and it will reduce environmental contamination.

Weed management. As tillage practices change, weed problems change. Common annual broadleaf weeds, such as velvetleaf and jimsonweed, may become less troublesome, whereas annual grass problems, such as fall panicum and large crabgrass, and perennial weeds, like hempdogbane, and common milkweed, may increase. As our knowledge of weed ecology and physiology increases, along with our growing arsenal of herbicides, we have more alternatives for managing weeds effectively in nearly any tillage or cropping system.

It is often said that no-till systems require more herbicide and higher weed-control costs. Although this may be true in some cases, research and recent experience indicate that good management in a no-till system can keep weed-control costs comparable to those for conventional tillage systems without increasing herbicide expenditures.

Corn following soybeans or corn following corn. The common practice of rotating corn with soybeans makes reducing tillage practices very easy for Illinois producers. No-tilling corn into soybean stubble has been very successful. Good weed control can be attained, and several management options are available. Weed control in corn planted no-till into corn residue is more difficult but can be successful if management is appropriate. Three options are outlined here.

1. Herbicides applied early preplant. The herbicide is applied before weeds emerge, about 15 to 45 days ahead of planting, to take advantage of any additional spring rainfall needed for herbicide mobilization. If winter annual or perennial weeds are present at the time of application, a "knockdown" herbicide may be required. Herbicide applications made closer to corn planting are at a greater risk of receiving inadequate rainfall for mobilization, whereas applications made too early in the spring may not provide season-long weed control.
2. Incorporated treatments for corn following soybeans. Disking or field cultivating for incorporation broadens the number of herbicide options as well as improves weed control when rainfall is low after herbicide application. Although tillage for incorporation may expose the soil for several weeks until the corn canopy forms, this problem may not be serious for many Illinois fields.
3. Controlling weeds postemergence in corn. Successful postemergent control requires proper identification of weeds and timely application of an appropriate herbicide. Postemergence herbicides are available for control of most annual broadleaf weeds and for the suppression of several perennial broadleaf weeds. Postemergence herbicides for annual grass control in corn are also available, and new products on the horizon may provide even greater flexibility.

Soybeans following corn. Weed-control strategy for no-till soybeans following corn is much the same as in no-till corn without incorporation opportunities. Early preplant treatments that include a "knockdown" herbicide work well.

A number of postemergence herbicides for use in soybeans control both grass and broadleaf weeds. The likelihood of success depends on properly identifying weeds when the plants are young (2- to 3-leaf grass and 1- to 2-leaf broadleaves), on choosing the appropriate products and rates of application, and on applying herbicides when weeds are most susceptible to them. Planting soybeans with a drill in narrow rows has been effective in shading late-emerging weeds and fits well into postemergence weed-control strategies.

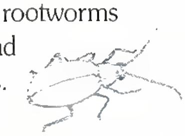
No-till corn and soybeans in legume and grass sod. Small-seeded legumes and grasses may be used for set-aside land, for pasture, hay, or for a cover crop preceding corn or soybeans. The grass or legume cover not only helps reduce soil erosion, but it also may suppress weed germination and growth. Some research indicates that less herbicide may be needed because of weed suppression.

These grass or legume species represent a unique opportunity for no-till, but careful management is very important.

Ridge till. A ridge tillage system is used successfully by some farmers in Illinois. Ridge till represents a unique opportunity for herbicide banding, which will reduce the rate of herbicide used per acre and the cost of control. Although ridge till may not completely preclude incorporated herbicides, greater reliance is generally placed on surface-applied preemergence herbicides and selective postemergence treatments. Weed control in ridge till has been successful, and many of the same principles and considerations apply as for the other tillage systems.

Insect management. Four major insect pests affect Illinois crops: the northern corn rootworm, the western corn rootworm, the black cutworm, and the European corn borer. These insects have long been pests of corn regardless of the tillage system. Insect pests of soybeans occur sporadically in Illinois, and adoption of conservation tillage has not led to any new problems.

Corn rootworms. Infestation of corn pests has been studied under conditions of reduced tillage and no-till. Oviposition by northern and western corn rootworms is similar in conventional and conservation tillage systems. Larval survival and adult populations are also not influenced by tillage conditions. Planting and maturity dates of corn are more important agronomic influences on the severity of corn rootworm infestations and damage.



Although the use of soil insecticides is recommended when corn is planted annually in the same field, the decision to use chemical control should be guided by scouting for adult beetles in the late summer to determine potential infestation for the subsequent season. The use of insecticides can be avoided altogether by rotating corn and soybeans because corn rootworms cannot survive on soybean roots and lay few eggs in soybean fields.

Black cutworms. This pest does not successfully overwinter in Illinois, but it migrates from southern states in the early spring. Female moths are attracted to weedy fields where they will lay their eggs. No-till and other agronomic practices that encourage the establishment of weeds, especially winter annual and perennial weeds, increase the potential for problems with these insects. Conservation tillage, however, should not affect successful management of black cutworms nor require increased use of insecticides.

Fields susceptible to black cutworm infestations should be scouted to determine

Monitoring Water Quality

Thomas J. Bicki and Michael V. Miller

Does the current level of pesticide and nitrogen fertilizer use pose a threat to our water resources? Recent events, such as nitrate concentrations exceeding the National Drinking Water Standard in the Danville public water supply and the detection of pesticides in several municipal wells, have raised the question for both farmer and environmentalist. And, although this question is too complex for a simple yes-or-no answer, sophisticated analytical techniques can now be used to detect minute quantities of contaminants in public and private supplies of drinking water.

Monitoring and testing of surface water and groundwater for contaminants from point sources, such as industrial sites, landfills, and leaking underground storage tanks, are normally restricted to a site-specific area because a recognized source and a pathway for contaminant travel to adjacent water supplies are present. But evaluating the impact of pesticide and fertilizer use on our water resources requires quite different monitoring strategies because the contaminant source is spread over a large area and has multiple pathways to water sources.

Retrospective monitoring studies examine water quality after prolonged or repeated use of a pesticide or fertilizer in an area. The U.S. Geological Survey's programs for monitoring the quality of surface water, NASQAN (National Stream Quality Accounting Network) and NAWQA (National Water Quality Assessment), and the Illinois Environmental Protection Agency's study for monitoring municipal wells are used to characterize the extent of contaminants in water over a large area or region and typically involve extensive sampling. These monitoring studies provide an overview of water quality, but identifying the exact source of contaminants is difficult if not impossible.

Small-scale retrospective monitoring studies, such as the one conducted in Mason County by the State Geological

Research has revealed that pesticides can leach to groundwater through normal field application and can be carried in runoff to surface water.

Survey and State Water Survey, focus on evaluating the water quality for a limited number of samples in a specific area. They survey the groundwater quality for that area; but, again, the actual source of contamination is difficult to determine.

In contrast, prospective monitoring studies, such as those being conducted in Mason, Logan, and Champaign counties by the University of Illinois Agronomy Department, the State Geological Survey, and the Natural History Survey, evaluate the fate and transport of potential contaminants to groundwater in a clearly defined area after pesticide and fertilizer application. Prospective monitoring studies can determine if a specific compound will leach to groundwater in a particular locale under a certain set of conditions. The interaction of soil and hydrogeologic characteristics, management practices, climatic conditions, and chemical characteristics of the contaminant affect its fate and transport in soil and into groundwater.

Contaminant levels in water fluctuate in response to seasonal variations in precipitation and groundwater recharge (replenishment), timing of pesticide and fertilizer applications, and management practices. As a result, repeated sampling and testing of drinking water over long periods, called time-series monitoring, are needed to assess water quality accurately.

The increasing public awareness and concern about water quality in Illinois have resulted in more detailed monitoring of surface water and groundwater supplies; and those efforts are expected to intensify in the coming years.

Thomas J. Bicki, assistant professor of pedology, Extension agronomy, and Michael V. Miller, associate geologist, Illinois Geological Survey

if the infestation has reached the economic threshold. If economic injury is probable, then a rescue spray of a pyrethroid insecticide can control feeding damage. Pyrethroid insecticides are used at rates 10 times lower than conventional organophosphate and carbamate insecticides, and they have relatively low mammalian and avian toxicities.

European corn borers. Successfully overwintering in corn stalks in Illinois, these insects produce two generations during the growing season. They are pests in both conventional and no-till systems. Destroying the crop residue by tillage was thought to reduce the overwintering population of corn borers. Conservation tillage, however, has not been observed to cause an increase in problems with them. They are controlled by relying on varieties resistant to first-generation larvae and by scouting for egg masses to determine whether second-generation larvae will reach the economic threshold. Pyrethroid insecticides may be used for corn borer control. In addition, a microbial insecticide, which consists of a bacterium pathogenic to corn borers, is now registered for use against them.

Conclusions

Overall, conservation tillage has had little impact on the severity of major pest infestations in Illinois corn and soybean fields; therefore, it has not caused increased use of pesticides. Fertilizer use increased before the widespread adoption of conservation tillage practices. Although much research is directed to less chemically intensive crop-production systems, agrochemicals will remain an important component of modern farming practices.

The potential for adverse environmental effects from agrochemical use has been recognized, but adopting the best management practices can greatly reduce its impact. Management practices are flexible enough to be effective in no-till systems. Increased application of the IPM philosophy to crop protection will complement the growing use of conservation tillage to maintain a productive agriculture without sacrificing environmental quality.

Allan S. Felsot, economic entomologist, Illinois Natural History Survey; Louis F. Welch, professor of soil fertility, Department of Agronomy; William S. Curran, Extension agronomist; Ellery L. Knake, professor of weed science and Extension agronomist; William G. Ruesink, professor and head, Office of Agricultural Entomology

Groundwater Quality and Human Health Concerns

Joseph W. Pankau

Over 95 percent of this nation's rural and over 50 percent of its urban residents depend on groundwater to quench their thirst. Groundwater has always been a vital part of life, yet only recently have we begun to focus on the groundwater-quality problems caused by our ignorance and neglect. As we face the possibility of increased amounts of chemicals in our groundwater supplies with greater usage of conservation tillage, concern for human health has intensified.

"For the first time in the history of the world," Rachel Carson writes in her book, *Silent Spring* (1962), "every human being is now subjected to contact with dangerous chemicals, from the moment of conception until death." The threat to human health from the use of chemicals is brought home to us, for instance, by the fact that childhood leukemia rates may be related to the family's use of pesticides and to parental occupations involving the use of chlorinated solvents and spray paint.

Concern due to lack of information

Also a source of urgent concern is the lack of data on the impact of ingesting minute concentrations of chemicals in groundwater. Yet we know, for example, that heptachlor, a pesticide, goes through the food chain to mother's breast milk. Data on the long-term effects of pesticide exposure, nevertheless, are difficult to obtain, given the delayed onset of diseases and uncertainties about when and how exposure may have occurred.

We have also discovered that two-thirds of the nitrogen applied in rural and urban settings goes up into the air, moves into surface water, or goes down into groundwater. We want and need to know what can be done to increase plant utilization of this nitrogen and to improve nitrogen management.

The challenge is to educate effectively

Hope for greater well-being in the future rests on wiser use of all chemicals but especially on wiser use of those chemicals that cause the most consumer anxiety. Prevention is the prescription for eliminating groundwater pollution: once contaminated, groundwater is extremely difficult, if not impossible, to restore to its original quality. Groundwater education, therefore, has become one of the major challenges for Cooperative Extension services.

Communicating and reducing health risks. Risk assessment is the scientific process of estimating the threat that environmental contaminants pose to human health. Real health risks must be communicated in a timely fashion.

We are beginning to recognize that how people perceive a risk determines how they will respond to it. The challenge is to alert people when they should be alerted and to reassure them when they should be reassured. Sometimes people need to be calmed down, but the ultimate means of risk reduction — reducing the risks to health from exposure to chemicals — should be rational alertness, not passive trust.

Vigilance is necessary, for toxins that affect the human nervous system can mistakenly be attributed to other causes, such as fatigue, advancing age, or one's lifestyle. Instead of investigating the real causes of lassitude or inattention, some people blame themselves for their weakness and ignore increasing danger signals.

Sharing the responsibility for risk reduction. The responsibility for risk reduction, however, must be shared. The most common sources of information about the dangers of exposure to certain chemicals are people who are also professionally inclined to ignore consumers' anxiety about health risks. When concerned consumers are ignored, they become more concerned, cry out louder, and listen less. Reminded that few crop chemicals carry information about the maximum contaminant levels for groundwater, experts, on the one hand, should accept the challenge of communicating risks as well as assessing them. Consumers always have the right to know the risks involved. Consumers, on the other hand, should use common sense and follow the rules on the labels of chemicals whether they are used in the home or in industrial or farm operations.

Understanding the hydrologic cycle. Misconceptions about the circulation of water through evaporation and precipitation and the distribution of water on the

surface and underground are part of the communication problem. A common misconception is that groundwater consists of large underground rivers and lakes similar to those above the ground.

The hydrologic cycle actually consists of rainfall that either evaporates back into the atmosphere or runs off into rivers, lakes, and streams. Some rainfall sinks into the ground to become groundwater. Its quality is affected by that of its rain source as well as by surface soil contaminants and the reaction of the water with the rocks through which it passes.

Determining drinking water standards. Adding to the confusion of issues involved is many people's misconception that current drinking water standards guarantee that the cup of water you drink from the tap will be absolutely safe. Based on the available knowledge, these standards reflect sound scientific judgment and awareness that each contaminant poses a potential threat to human health. The risk is evaluated in laboratory animal toxicity studies and in the records of human exposure, usually in the work place. The standards help provide reasonable assurance that water is safe to drink, but no guarantee of zero risk.

The standard test performed on drinking water samples is for nitrates, the primary health concern being the reduced form of nitrate called nitrite. In adults, ingested nitrates are absorbed by the body and eliminated in the urine. In three- to six-month-old infants, however, little natural stomach hydrochloric acid is available to digest nitrate. Their stomach bacteria turn it into toxic nitrite, making their bodies incapable of carrying oxygen to the cells. Other acute health effects of contaminants in groundwater include vomiting, skin rash, and lung irritation.

The levels of contaminants in drinking water, however, are seldom great enough to cause acute physical symptoms. Long-term exposure to small amounts of chemicals is more likely to cause chronic health problems.

Thinking about the impact of our actions will help us secure not only high-quality water but also an environment that maximizes our health and well-being.

Joseph W. Pankau, assistant professor of foods and nutrition and Extension health education specialist, School of Human Resources and Family Studies

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Protecting and conserving water

We need to protect the quality of our water and conserve water because we need to be in a mutually supportive relationship with nature. Some water-saving methods are listed here.

Be aware of your water source and supply. Find out where your water originates and if your water supply has been tested recently. Learn how it is protected from contamination.

Learn to conserve water. Improve your water use and management. Repair leaking faucets and toilets. Apply water to lawns, gardens, and crops judiciously.

Use and dispose of household lawn, garden, and crop chemicals wisely. First determine whether the use of a particular chemical is really necessary. Then buy only what you need and apply the minimum amount that will do the job.

Minimize the production of waste materials. Do not buy more than you can use. Compost vegetable wastes and recycle newspaper, aluminum cans, and glass.

Paying the Costs of Erosion Control in Illinois

Richard L. Farnsworth and John B. Braden

U.S. farmers and ranchers produce sufficient quantities of food and fiber to meet the demands not only of our nation but also of a large part of the rest of the world. The relative success of the U.S. agricultural sector can be attributed to fertile soils, a favorable climate, hard work, a competitive marketplace, and this nation's commitment to agricultural research.

Success, however, does not come without problems. Preserving the vital connections between people and the ecosystems of the planet on which they live is becoming troublesome to the agricultural sector and to society as a whole. Perceived and real harm to health, damage to the environment, losses of fish and wildlife, and degradation of resources associated with modern agricultural practices have prompted local, state, and federal policymakers to take action.

Legislated guidelines

In 1977, the Illinois General Assembly passed the Erosion and Sediment Control Program and Standards law. The average annual rate of erosion has dropped somewhat since then (Figure 1), but not enough. According to this law, by the year 2000, erosion on the state's soils should be at or below tolerable levels called "T levels": maximum allowable average annual erosion rates that ensure continued productivity of the soils. These guidelines are also expected to reduce substantially the amount of eroded soil and attached farm chemicals that reach waterways and lakes.

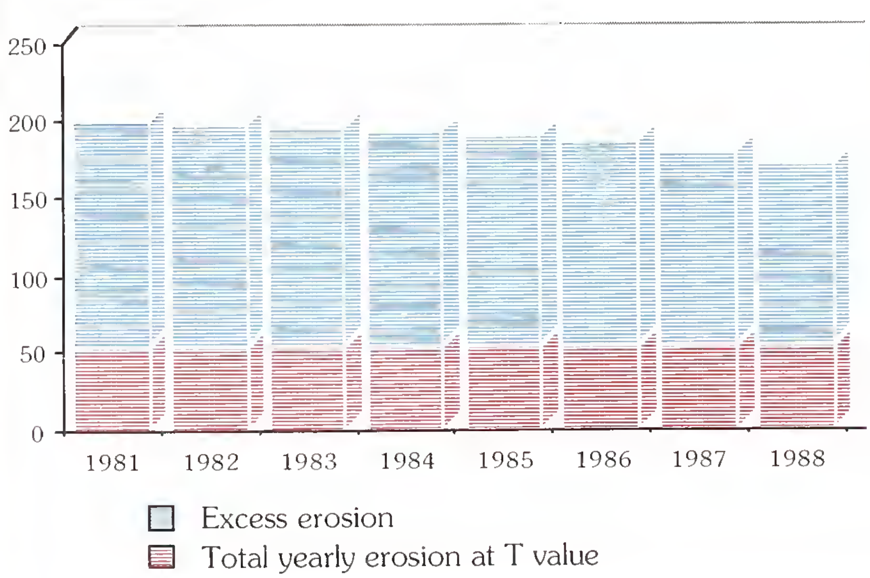


Figure 1. Total Annual Erosion Rate in Illinois, 1981 to 1988.

At the federal level, the Food Security Act of 1985 contains a section on soil conservation and water quality. Three provisions — the swampbuster, sodbuster, and conservation-compliance provisions — promote broader protection of the nation's biological, soil, and water resources.

In addition, the Conservation Reserve Program pays producers to remove their highly erodible lands and lands adjacent to waterways from row-crop production in order to reduce erosion, improve water quality, and promote expansion of recreational and commercial water activities. Except for an unusually large sign-up in early 1987, when farmers received a bonus for retiring corn base acreage, Illinois's participation in this program has risen steadily, but it still barely exceeds 10 percent of the state's 4 million eligible acres (Figure 2).

Passage by Congress of the Clean Water Act in 1987 also reinforces the commitment of this nation to better usage of its natural resource bases. The act specifically directs each state to develop a management plan for reducing nonpoint-source pollutants in surface waters, that is, pollutants that cannot easily be traced back to a specific source, such as a farm field. The impacts on agriculture will be pronounced because the most widespread pollutants are sediment and chemicals from agricultural lands.

Answers needed

Two important questions, therefore, must be answered. First, what are the costs of implementing acceptable erosion and sediment guidelines? Second, who should pay for conserving soil and improving water quality?

Costs of control. For Illinois, acceptable erosion levels mean the application of conservation practices and structures that jointly reduce sheet and rill erosion to each soil's T level and protect the soil surface both from ephemeral gully and gully erosion due to the concentrated flow of water. Keeping soil erosion at or below T levels would indefinitely maintain the inherent productivity of our soils.

Two studies — one by the University of Illinois for the Illinois Department of Energy and Natural Resources entitled "Financing Alternatives for Agricultural Nonpoint Source Pollution Control Programs" and one by the Illinois Department of Agriculture entitled "T By 2000" — provide aggregate cost estimates for reducing erosion to acceptable levels.

In the University of Illinois study, researchers estimated the costs of applying management systems that reduced sheet and rill erosion to the state's guidelines on all soils (Figure 3). Soils were aggregated into eight groups with roughly similar physical characteristics and susceptibilities to erosion. For example, part of one group was formed by Flanagan, Herrick, Ipava, and Muscatine soils, which are dark and moderately dark soils, somewhat wet with good permeability, and moderately susceptible to erosion. Lumped together in another group were the highly susceptible soils, such as the light-colored forest soils with restricted permeability, including, for instance, Ava, Blount, Grantsburg, Hosmer, and Wynoose soils.

Dateline	Soil Loss Goals	
	≤ 5 percent slope	> 5 percent slope
	tons per acre per year	
January 1, 1983	4 to 20 (4 T or less)	4 to 20 (4 T or less)
January 1, 1988	1 to 5 (T or less)	2 to 10 (2 T or less)
January 1, 1994		1.5 to 7.5 (1.5 T or less)
January 1, 2000		1 to 5 (T or less)

Note: Ranges are indicated because of differences in soil type.

Figure 3. Illinois Guidelines for Achieving Tolerable Average Annual Soil Loss (T).

Cropland acres in each group were then divided into the following slope categories: A, 0 to 2 percent; B, 2 to 5 percent; C, 5 to 10 percent; D, 10 to 15 percent; E, 15 to 20 percent; F, 20 to 25 percent; and G, greater than 25 percent.

Farm production budgets were developed for the major crop rotations and tillage methods. Crop rotations included feasible combinations of corn, soybeans, wheat, oats, hay, and permanent cover. Tillage methods ranged from moldboard plow to no tillage.

For conservation practices, contouring and contour strip-cropping were options. Terraces and other conservation structures proved to be extremely costly measures for controlling sheet and rill erosion, so they were kept only as measures for controlling concentrated water flow.

The minimum estimated annual costs of implementing approved conservation systems for sheet and rill erosion throughout the state amount to $46.3 million or an average of about $2 per cropland acre or $0.45 per ton of soil saved.

None of the A-slope soils required erosion-control measures. For soils with a B slope, average costs per ton of soil saved ranged from $0.71 to $1.86; C-slope soils, from $0.21 to $1.71; D-slope soils, from $0.05 to $1.60; E-slope soils, from no cost to $1.26; F-slope soils, from no cost to $1.08; and G-slope soils, from no cost to $0.51.

Interestingly, erosion-control costs decline as the slope increases, for much of the highly sloped land is already in permanent pasture or meadow. Furthermore, the model indicated that the least costly shift for producers is to pasture or hay production rather than to costly

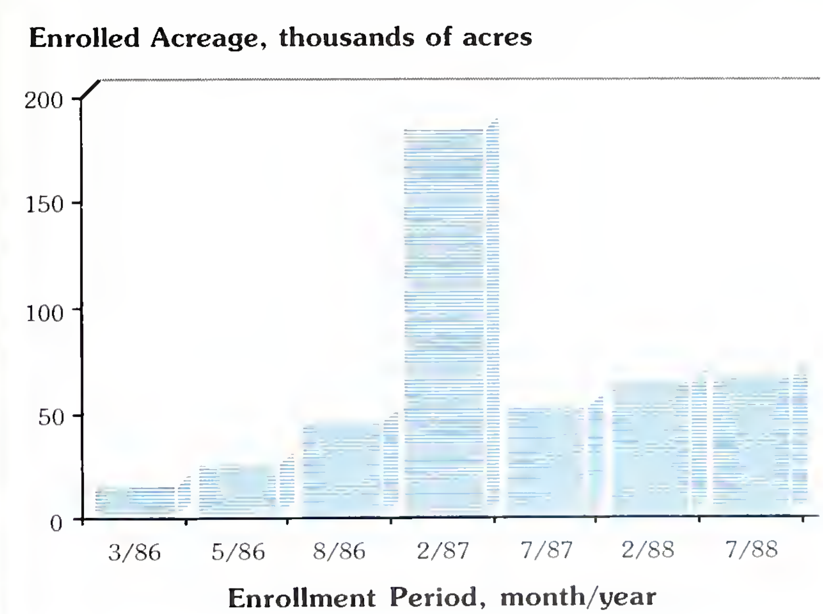


Figure 2. Illinois Enrollment in the CRP, 1986 to 1988.

conservation measures. These measures keep the land in annual crop production with marginal, potential profit.

The total cost of meeting T values presently equals \$46.3 million a year. A 50-year, \$46.3-million cost stream, therefore, equals \$579 million in 1988 dollars. To obtain this figure, we have assumed a time value of money of 8 percent, which includes the real and inflationary rates of interest. A dollar invested today at 8 percent interest will equal \$1.08 in a year, and an initial investment of \$579 million at 8 percent is equivalent to yearly payments of \$46.3 million over 50 years.

In the study on T by 2000 conducted by the Illinois Department of Agriculture, experts estimated that an additional \$1.039 billion are needed to pay for grassed waterways, terraces, sediment control basins, grade stabilization structures, and other enduring conservation structures. These structures, when applied with conservation management systems, protect the soil surface from other forms of erosion caused primarily by concentrated water flow.

For Illinois, the estimated total cost of implementing conservation management systems (\$0.579 billion) and applying enduring conservation structures that meet the state's erosion and sediment guidelines (\$1.039 billion) equals \$1.618 billion. In practice, costs may be higher for several important reasons.

First, researchers assumed yields were unaffected by changes in tillage: technological advances and better management would help producers counteract yield discrepancies among tillage methods.

Second, the most cost-efficient management system and a less erosive crop rotation were assumed as part of the erosion-control plan. Many farmers, however, opt to apply more costly structural conservation measures in order to retain the flexibility of using different crop mixes in response to changes in crop prices.

Finally, because of problems with cash flow and the availability of credit, some producers may be unable to adopt the least expensive practices. With these qualifications in mind, the cost estimates provide a reasonable basis on which to judge the magnitude of the problem with erosion control in Illinois.

Who will pay for controlling erosion? Both the state and federal governments have programs that provide cost-share funds primarily for the construction of enduring conservation structures. Producers who work with the Soil Conservation Service and the Soil and Water Conservation districts and develop a conservation plan are eligible to apply for these cost-share funds.

Under "Build Illinois," the state's Conservation Practices Program (CPP)

Options for Meeting Farm Bill Regulations on Conservation

William G. Beeler

Under the provision on highly erodible land of the Food Security Act of 1985 (Title XII, Subtitle B), producers must keep erosion on highly erodible cropland within acceptable levels to retain eligibility for certain program benefits of the U.S. Department of Agriculture.

The Universal Soil Loss Equation or the Wind Erosion Equation can be used to predict erosion caused by water or wind. Any soil that can erode at eight times its tolerable rate is considered highly erodible. In Illinois, four million acres of this type are cultivated by seventy thousand farmers.

Penalties

Producers who fail to comply with conservation provisions could face severe economic loss: if one-half of Illinois's highly erodible land is corn base enrolled at the 90 percent level, the loss of deficiency payments would be \$142,560,000 or about \$20,000 per farm. Those failing to comply are also ineligible for commodity loans, federal crop insurance, wool payments, payments of the Conservation Reserve Program (CRP), home loans to farmers, and disaster payments.

Options

A producer has several compliance options under the conservation provisions of the act.

An approved plan. One is to adopt an approved conservation plan that will reduce excessive erosion on highly erodible cropland. Producers should check with the office of their county Agricultural Stabilization and Conservation Service (ASCS) and Soil Conservation Service (SCS) to see if they are farming any highly erodible land. If they are, they have until January 1, 1990, to develop an approved conservation plan, which must be in operation by 1995. Without an approved plan, producers may not drain any wetlands or break out any highly erodible grasslands or woodlands to grow crops.

Enrollment in the CRP. Another option is to enroll the highly erodible land in the CRP. This 10-year,

and Watershed Land Treatment Program (WLTP) each received $10 million over 5 years, beginning in fiscal year 1986. The objectives of CPP are to provide financial assistance to land users who install costly conservation practices and to help meet Illinois's guidelines for T by 2000. WLTP funds are targeted to critical watersheds. Producers in these areas may receive financial assistance to apply conservation structures that help meet the state's erosion guidelines and improve water quality.

The USDA's Agricultural Conservation Program (ACP) provides cost-share funds to producers who voluntarily comply with federal and state conservation regulations, control erosion and sedimentation, improve water quality, and maintain soil productivity. Payments to a producer typically do not exceed $3,500 a year. The most current data indicate that Illinois has $6.3 million in ACP funds for fiscal year 1989.

Specially funded private, state, and federal projects may create additional temporary funding, but overall funding does not meet the estimated total erosion-control costs of $1.618 billion. Without significantly higher levels of state and federal financial assistance, production costs will increase for Illinois producers as they implement mandated erosion-control measures, and these higher costs will cause contractions in other sectors.

As Illinois farmers produce less at higher costs,

- Agricultural support industries may experience lower sales;
- Consumers may pay more at the grocery store;
- Other states in the Corn Belt that do not follow similar guidelines may obtain a slight competitive edge; and
- U.S. agricultural products will be less competitive in world markets because of higher production costs.

But from a long-term perspective, protection of our agricultural and water resource bases also has a positive side:

- In rural communities, land improvement contractors, implement dealers, and other small businesses that provide the supplies and services for building enduring conservation structures will have more work. The money earned probably will remain in these communities and stimulate new jobs, which will partially offset declining employment on the farm and in production-support industries.
- Less sediment and farm chemicals in our nation's waterways and water bodies may reduce off-farm damages and stimulate growth in other economic sectors.
- Controlling erosion to sustain the productivity of the soil and to protect water quality will make Illinois and U.S. agricultural producers more competitive in the future. States or other countries that continue to exploit their resource bases for short-term, higher profits will probably encounter more severe erosion and sediment problems with more expensive solutions in the future.

Excessive erosion and the problems it causes in the agricultural sector and other sectors of the economy warrant better resource management. In Illinois, reducing erosion to tolerable levels and possibly improving water quality carry a hefty price tag. Complete control would cost an estimated $1.618 billion. State and federal cost-share monies for producers who are willing to meet state and federal guidelines are insufficient. Policymakers, therefore, will have to decide soon whether producers will bear the brunt of erosion-control costs or whether public funds will be channeled to assist farmers in limiting erosion and pollution.

Richard L. Farnsworth, assistant professor of agricultural economics and John B. Braden, associate professor of agricultural economics.

land-retirement program takes highly erodible land out of production. If two-thirds of the acreage in a field is determined to be highly erodible, that field qualifies for this program.

Enrollment offers some side benefits. For instance, producers may put filter strips between 66 and 99 feet wide along streams, lakes, and other waterways to control erosion and runoff. Producers may also enroll certain cropped wetlands as well as cropland adjacent to streams that is subject to scour erosion by out-of-bank water flows. For those enrolled in the CRP, these are cost-effective ways of preventing nonpoint-source pollution from emptying into water reservoirs.

Cost-sharing programs. Producers also have the option of using the ASCS Agricultural Conservation Program, which shares from 50 to 75 percent of the cost of adopting and installing conservation practices on erodible land that will be in crops. These soil-saving practices also save income for producers by eliminating much of the need for fertility-enhancing substances applied to cropland.

Cost-sharing for these practices is divided among several programs: one-year annual programs, long-term agreements that take several years to complete, and the forestry-incentive program that converts cropland into forestland. Financial assistance is also available from a program called Emergency Conservation, which helps repair cropland after a national disaster, such as flooding. Permission to participate in this program must be obtained from a county Agricultural Stabilization and Conservation Committee, which in turn obtains concurrence from Washington, D.C., before approving the request. In some situations, this very helpful program has also brought people into compliance with conservation measures while assisting with the repair work after a disaster.

William G. Beeler, state executive director, ASCS

The Food Security Act of 1985: Planning for Compliance and Profit

John Eckes, Harry Slawter, and Raymond Herman

The Food Security Act of 1985 (FSA) has revolutionized the planning and implementation of soil and water conservation in Illinois by linking eligibility for several popular federal farm programs to a producer's progress in controlling erosion on highly erodible cropland. The most commonly affected U.S. Department of Agriculture benefits include feedgrain and loan programs of the Agricultural Stabilization and Conservation Service, operating and ownership loans from the Farmers Home Administration, and crop insurance from the Federal Crop Insurance Corporation.

A statewide inventory has shown that USDA program participants currently farm about 4.9 million acres of cropland that can erode at 8 or more times the tolerable rate for maintaining soil productivity. With about 90 percent of Illinois producers currently participating in USDA programs, the FSA provides an incentive for developing a conservation plan to nearly everyone farming highly erodible cropland in this state. Many have never discussed their farming operation with a soil conservationist but are interested in the potential benefits from progressive soil and water management.

Need for affordable and practical systems

Our challenge is to show them affordable conservation systems with simple and practical techniques for reducing erosion. If some of the techniques already in use on many successful farms can be integrated into the management of all producers, the net effect on erosion would be substantial. The period from 1990 to 1995 for complying with FSA provisions, moreover, provides a reasonable time for producers to test and refine techniques into suitable systems.

To accomplish this huge educational task, local USDA agency personnel have enlisted the support of farm organizations, agribusinesses, and others to reach producers with information on conservation. By October 1, 1988, over forty thousand Illinois producers completed plans outlining conservation actions to be carried out before 1995.

Our joint efforts, therefore, have been successful, but a large part of the job lies ahead. Many farmers want to get their conservation systems started soon. They need the technology, encouragement, and financial support to refine the systems that work for them.

Many available options

What options for changing management systems are available? Without adding small grain or hay to crop rotations, all growers of corn and soybeans in Illinois will have a dozen or more options. These alternatives are based on types of tillage equipment as well as the direction and timing of tillage operations. Changes in tillage practices can effectively treat 60 percent of the total erosion targeted by the FSA in Illinois.

Conservation tillage. This practice of leaving at least 30 percent of acreage covered with crop residue after planting is the most commonly planned method. Two forms of conservation tillage, mulch till and no-till, can be practiced relatively easily and economically to reduce erosion on highly erodible land.

According to the 1987 National Survey of Conservation Tillage Practices published by the Conservation Technology Information Center, the use of mulch tillage is currently projected to be about the same in 1995 as it was during the past 3 years, and the use of no-till is expected to double (see the accompanying bar chart). As producers learn to farm with more crop residue on the soil, they will change the timing and number of their operations and make other adjustments to make their mulch-till techniques more effective in controlling erosion.

Complementary methods. Certainly, many other traditional conservation practices are needed and will be applied progressively to complement the first steps of the conservation system. The use of terraces, structures, and grassed waterways will be integrated as needed to manage runoff uncontrolled by simple agronomic practices. Adding small grain or hay to crop rotations is also a viable option for producers with that flexibility.

Groups to share information

Illinois producers wanting to get "an early start" on complying with FSA provisions have focused on changing tillage prac-

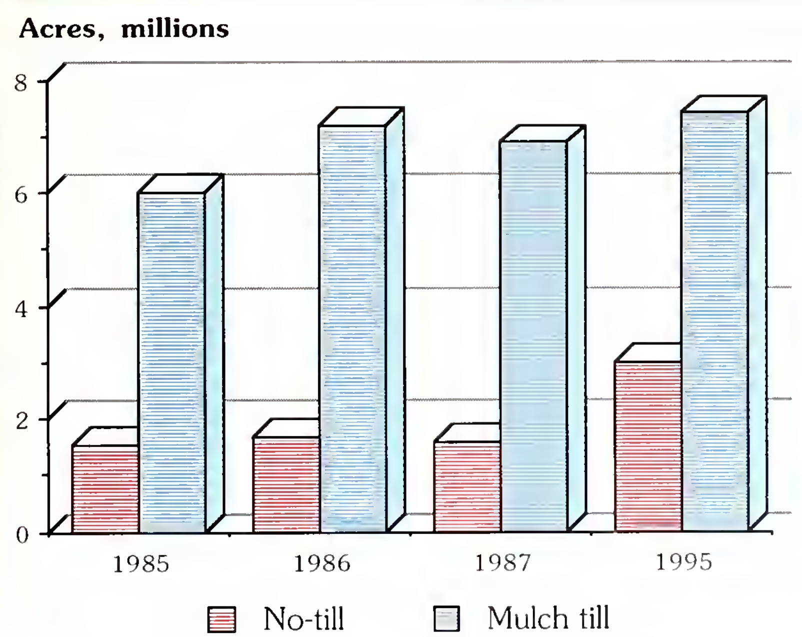
No-till corn is planted in the cover crop of this field.

Contour terraces and grassed waterways are two methods for achieving compliance.

tices. How can soil conservationists, Extension advisers, agribusiness representatives, and farmers work together to accelerate this and other conservation measures? Producers expect and deserve simple, concise, and accurate information on the effects of changing tillage practices or adding other components to their conservation systems.

According to the designers of the Conservation Systems Workshop — Richard Farnsworth, Robert Walker, and Raymond Herman, the primary technique will again be the group approach for informing farmers about their planning options. Local meetings will be organized so that industry and agency representatives can inform them about additional technology and so that successful farmers can relate their actual experiences with conservation tillage and other conservation practices.

While many provisions of the FSA will continue to be controversial, efforts to achieve compliance with them have focused attention on basic soil and water management. The real measure of their success lies in how we use this opportunity to accelerate cooperation between farmers and the organizations, businesses, and agencies that support them.



Conservation Tillage Trends in Illinois, 1985 to 1995.

Predictable changes

Although future farm-program authorizations will certainly change, incentives for compliance will probably continue to be offered. Concern about the movement of pesticides and nutrients into groundwater and surface water will get more attention and probably be treated in the same manner as concern about cropland erosion has been treated in the FSA.

Its compliance initiatives also support a plan adopted in 1984 by the Illinois Department of Agriculture and local soil and water conservation districts to reduce all cropland erosion to the tolerable level by the year 2000.

The FSA conservation-system approach to dealing with erosion will not result in the construction of every terrace or waterway needed on highly erodible cropland in Illinois, but it will help many producers experience the benefits of conservation for the first time. These benefits are an asset to their farm operation — with or without compliance. Let us work together to share the advantages of compliance and profit with all producers in Illinois.

John Eckes, state conservationist, Harry Slawter, assistant state conservationist, and Raymond Herman, state resource conservationist, all with the USDA Soil Conservation Service

In Progress

Conservation Systems Workshop

By 1990, an unprecedented number of farmers across the country will have developed conservation plans to comply with the 1985 Food Security Act. To facilitate the process, the Illinois Cooperative Extension Service has developed a workshop on conservation systems including a comprehensive package of planning materials for the U.S. Department of Agriculture.

Designed for use in workshops and classrooms, this package includes a 162-page manual, 98 overheads, five 12-minute slide programs, and a 17-minute videotape. These materials are in every district soil conservation office in the country and in many county Extension and conservation district offices.

In the Conservation Systems Workshop, producers first determine whether they should consider developing a conservation plan. Then they estimate the severity of erosion and other resource problems, select several conservation systems, analyze the economics of the alternative systems, and finalize their conservation plan.

This workshop on both water and wind erosion was designed for flexibility. It allows instructors to take a short or more comprehensive approach to conservation planning.

To obtain a price list or other information, write or call the distributor: Vocational Agriculture Service, College of Agriculture, University of Illinois at Urbana-Champaign, 1401 South Maryland Drive, Urbana, Illinois 61801. The telephone number is (217)333-3871.

Conservation Systems Workshop: The Sequel

Transferring a conservation plan from paper to the field is a formidable task. For this reason, the Illinois Cooperative Extension Service has been commissioned to develop a nationwide educational program that teaches producers how to implement conservation plans.

The new program will serve as a follow-up to the University of Illinois's Conservation Systems Workshop, which was created in 1987-1988 to teach producers how to develop conservation plans (see accompanying story). But conservation planning is only half of the job. The Food Security Act of 1985 also stipulates that conservation plans must be fully implemented before 1995 if producers wish to plant row crops on highly erodible land. Otherwise, these producers risk the loss of federal support payments.

Like the Conservation Systems Workshop, the conservation-implementation program will include overheads, slide programs, and an instructor's manual.

"About two-thirds of the program will discuss no-till and reduced tillage practices, which often serve as the heart of conservation plans," says Richard Farnsworth, University of Illinois Extension agricultural economist. "The remaining one-third will cover agronomic structures, such as contouring and strip-cropping, and mechanical structures, such as grassed waterways."

Now in its early stages, the project should be completed by spring 1990.

Land and Water Series Covers Wide Range of Issues

Agriculturalists today face no shortage of questions about natural resources. The Land and Water fact sheet series of the Illinois Cooperative Extension Service ensures that there is no shortage of answers.

This award-winning series now includes 14 publications, covering topics that range from erosion control and pasture management to groundwater quality and residue management. Most of these easy-to-read fact sheets are from four to six pages in length except for an eight-page publication on weed, insect, and disease control in reduced tillage and a 12-page publication on wells.

To obtain a complete listing or to order copies, write to Land and Water fact sheets, 305 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801. The telephone number is (217)244-2807. One copy of each publication is free.

New Resource for Managing Nitrogen Applications

Producers of corn and other crops can now more easily time the application of nitrogen and recognize soils that will readily lose nitrogen through denitrification and leaching because of the recent publication of Bulletin 784, *Nitrogen-Loss Potential Ratings for Illinois Soils* by John D. Alexander. Formerly, Alexander was an associate professor of pedology in the Department of Agronomy at the University of Illinois. This bulletin summarizing his research on the properties of Illinois soils in relation to nitrogen management indicates the rating for potential nitrogen loss of virtually every soil in the state.

With the aid of its five tables and six maps, producers can make use of information on nitrogen management found in the current *Agronomy Handbook* and other publications. For instance, they can determine which soils will probably lose more of the nitrogen applied in the fall.

While assembling and interpreting this data, Alexander estimated the acreage of individual soils in each of the fifty soil associations, information that may appear separately in a future publication. □

Sustainable Agriculture

Sustainable agriculture is talked about as a new way of farming, but research on this subject by the Illinois Agricultural Experiment Station dates back nearly a century. As early as 1901, Cyril G. Hopkins was conducting research on soil fertility with the idea that a farmer should pass along "land that is richer, than when he took over its management."

The Illinois AES defines sustainable agriculture in terms of management strategies that enhance the natural resource base and ensure an abundant safe and nutritional supply of food. It emphasizes the development of farming systems that are productive, cost-effective, soil-conserving, and protective of the environment and human health.

The objectives of sustainable agriculture reflect the needs of society today. The public is concerned about the long-term effects of certain agricultural technologies and practices on water quality and erosion, food safety, and human and animal health.

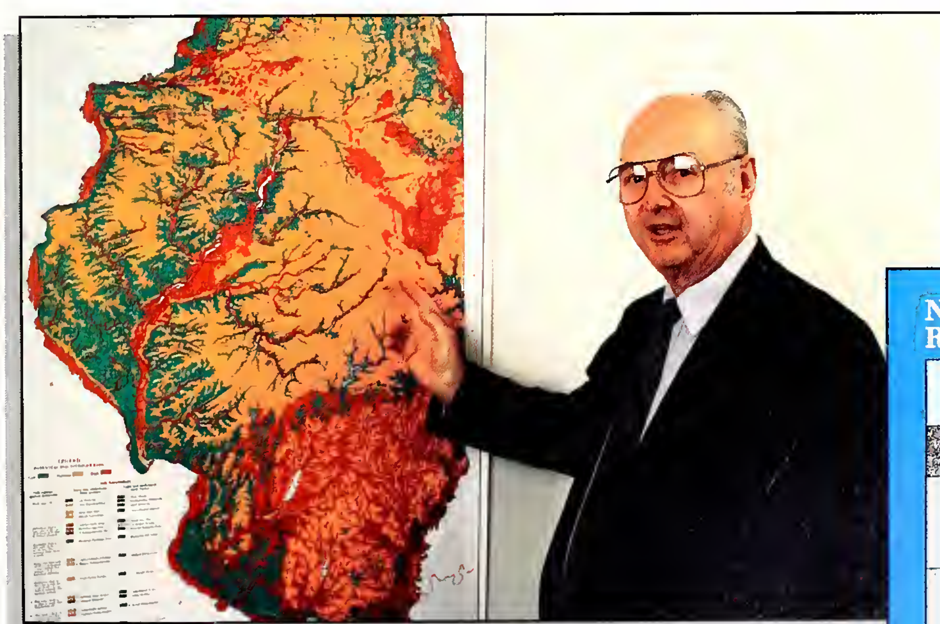
Farmers share those concerns, as well as concern for the future of farming. Agriculture has gone through a severe financial crisis, and the outlook is for continually rising input costs. Those who are committed to staying in the business of farming must be committed to sustainable agriculture, a system of farming that is environmentally sound, socially responsible, and economically competitive.

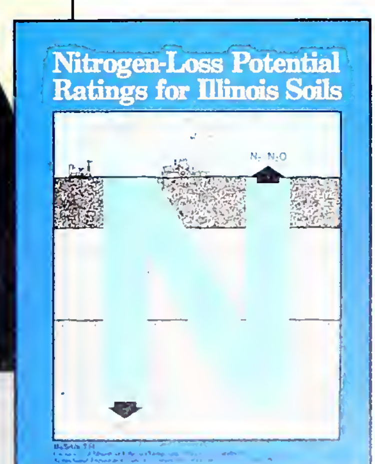
This year, the Illinois AES is proposing several new research projects designed specifically to support sustainable agriculture. These projects have much research to build on, for although sustainable agriculture is not the stated objective of most current Illinois AES projects, many contribute to the development of sustainable systems.

One of the most successful examples of research relevant to sustainable agriculture is interdepartmental work supporting Integrated Pest Management (IPM), a program that integrates pest control tactics with production practices. Some IPM programs have eliminated unnecessary pesticide applications, thus effectively reducing the cost of pest control and the potential for adverse environmental and health effects from pesticides.

Information applicable to sustainable agriculture also comes from Illinois AES research in the areas of tillage, forages, fertility, economics, and water quality.

In addition, scientists are using genetic engineering to improve biological control of insects and plant diseases; develop crops resistant to herbicides, diseases, and insects; engineer rumen microorganisms to improve forage digestion; and improve animal health and productivity. Value-added research is opening up new markets through development of new products from commonly grown crops.





John D. Alexander (above) points out areas in Illinois that have high, medium, and low rates of potential nitrogen loss on his wall-sized, four-color map, published recently with Bulletin 784 (right) of the Illinois Agricultural Experiment Station.

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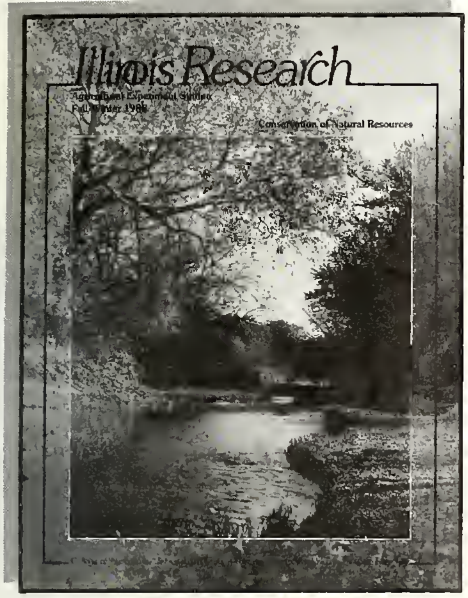

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